DRAFT

FOCUSED FEASIBILITY STUDY ADDENDUM

SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

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1.0 INTRODUCTION

This Focused Feasibility Study Addendum (FFSA) for the South Cavalcade Superfund Site (Site) located in Houston, Texas has been prepared by Key Environmental, Inc. (KEY), on behalf of Beazer East, Inc. (Beazer). The location of the site is depicted on Figure 1-1 and the general site arrangement is depicted on Figure 1-2. The FFSA has been prepared to document the evaluation of additional remedial alternatives (above and beyond those evaluated in the Focused Feasibility Study) for potentially impacted soils and groundwater in the northern portion of the Site.

A Focused Feasibility Study (FFS) was first completed for the Site in 2007. The Focused Feasibility Study was subsequently revised via multiple iterations in response to comments from the United States Environmental Protection Agency (USEPA) Region 6 and the Texas Commission on Environmental Quality (TCEQ). A final FFS Report was submitted to the USEPA and TCEQ in April 2011 (KEY, April 2011). The final FFS Report includes a summary of relevant background information, including, but not limited to, a detailed Site description and a conceptual site model, as well as evaluation of various remedial alternatives for the entirety of the Site (the background information provided in the FFS Report is not reiterated herein but is incorporated by reference).

As discussed in the final FFS Report, the following remedial action objectives (RAOs) were proposed for the Site:

- Prevention of dissolved phase plume migration beyond current limits; and,
- Prevention of future exposure to source material and impacted groundwater.

The first RAO is achieved when the dissolved phase groundwater plume is stable. Compliance with this RAO can be demonstrated by implementation of a groundwater sampling and analysis plan. The second RAO can be accomplished by the establishment of institutional controls prohibiting the use of groundwater within the Technical Impracticability Zone as propsed in Section 2.2 of the final FFS Report.

The Final FFS Report, as well as other relevant documents, was submitted to USEPA Headquarters for review in 2011. In addition to the Final FFS Report, a Technical Impracticability (TI) Demonstration Report (KEY, March 2011), and a Natural Attenuation (NA) Technical Memorandum (KEY March 30, 2011) were submitted for USEPA Headquarters review.

USEPA Headquarters requested that additional technologies be evaluated. Consequently, a Technology Screening Evaluation (Matrix) was prepared and provided to USEPA Region 6 and TCEQ. A copy of the Technology Screening Matrix is provided as Appendix A. Additionally, a site visit and meeting with representatives of USEPA Region 6, USEPA Headquarters, TCEQ and Beazer were held on December 14, 2011. Site and project background information was presented during the meeting. Presentation materials are provided in Appendix B.

As a result of the review process, and as a result of the December 14, 2011 project meeting/site visit, USEPA Headquarters, USEPA Region 6, and TCEQ indicated that the conclusions of the FFS and TI Demonstration are appropriate for the southern portion of the Site. For the northern portion of the Site, USEPA requested a detailed evaluation of additional treatment alternatives. Beazer was requested to evaluate two specific potential remedies for this area:

- In-Situ Chemical Oxidation (ISCO)
- In-Situ Solidification/Stabilization (ISSS)

These alternatives are in addition to the four alternatives evaluated in the final FFS. The four FFS alternatives were identified as a result of discussions between Beazer, USEPA, and TCEQ. The four FFS alternatives were as follows:

- Alternative 1 - No Further Action
- Alternative 2 - Monitored Natural Attenuation with No Further Action for Source Zone
- Alternative 3 - Monitored Natural Attenuation with Continued Source Removal
- Alternative 4 - In-Situ Solidification/Stabilization (S/S) of Accessible Source Materials

The MNA alternatives listed above would require a TI Waiver of groundwater remedial goals within the TI Zones and institutional controls to prohibit groundwater use within the TI Zones in perpetuity.

The area of interest for the purposes of this FFSA is depicted on Figure 1-2. Figure 1-2 also depicts the planned location of the right-of-way reportedly acquired by the Harris County Toll Road Authority for the Hardy Toll Road Extension which will abut the Site to the west. Figure 1-2 also displays the inferred extent of source material (DNAPL) in the North Area which constitutes the area of interest for the purposes of this FFSA.

As is shown on Figure 1-2, potential source materials in the North Area are confined to the Site. The NAPLs at the Site are creosote and coal tar which are slightly denser than water. Creosote and coal tar are much more viscous than groundwater (by an order of magnitude or more). The high viscosity of the DNAPL significantly inhibits its mobility in the subsurface and the ability to remove of significant quantities of DNAPL within a reasonable time. This effect is exacerbated by the heterogeneous and low permeability aquifer materials beneath the Site.

DNAPL is present within three hydrostratigraphic units, the shallow zone (0 to 20 feet below ground surface [ft-bgs]); the intermediate aquitard (20 to 50 ft-bgs) and intermediate zone (50-60 ft-bgs). The inferred extents of DNAPL in each of the three zones are shown on Figure 1-3. The inferred limits of DNAPL were determined by

- Visual observation of DNAPL in soil borings;
- Measured DNAPL accumulation in groundwater wells;
- Total PAHs greater than 100 mg/kg in soil;
- Total aromatic hydrocarbon concentrations greater than 1000 mg/kg in soil; and,
- Groundwater concentrations that approach the effective solubility of naphthalene contained in creosote (approximately 12 mg/L).

In practice, however, the delineation was based almost entirely on the first criteria (visual observation of DNAPL in soil borings), because of an extensive borehole drilling program conducted during the RI.

The DNAPL does not exist as a recoverable pool of liquid. Rather, the vast majority of the source material exists as non-recoverable residual DNAPL which is confined to the more permeable zones within the predominantly low permeability heterogeneous soil matrix. The combined effect of these geologic conditions and the DNAPL physical properties results in the distribution of DNAPL dispersed in a residual state over a broad area, although the mass in any given porous media volume may be relatively small.

The inferred areal extent of DNAPL for each zone is as follows:

- Shallow Zone – 184,000 square feet (4.2 acres);
- Intermediate Aquitard – 233,000 square feet (5.3 acres); and,
- Intermediate Zone – 166,000 square feet (3.8 acres).

The residual DNAPL is immobile even under enhanced hydraulic gradient conditions as a result of capillary tension in the soil. The limited effective solubilities of creosote and coal tar constituents prevent removal of significant mass via groundwater extraction. The water soluble fraction of creosote or coal tar represents less than 0.01% of the total mass of source material. The residual DNAPL will persist for many decades as a source of dissolved constituents unless the entire residual mass is addressed in the remediation program.

Subsequent to the December 2011 project meeting and Site visit (i.e., on February 8, 2012), USEPA Region VI forwarded an E-mail requesting that Beazer evaluate the possibility of the use of two innovative technologies (Self-Sustaining Treatment for Active Remediation [STAR®] and Surfactant-Enhanced Product Recovery [S-EPR]). These potential technologies were reviewed and were found to be inappropriate based on Site geologic and source-strength considerations as well as historical pilot study results (for surfactant soil washing). Preliminary technology evaluation reviews were prepared for these two additional technologies and these reviews have been incorporated herein as Appendices C (STAR®) and D (S-EPR).

The remainder of this FFSA develops and evaluates remedial alternatives based on the two aforementioned remediation technologies (i.e., ISCO and ISSS). Given USEPA's interest in accelerating (if possible) Site restoration, the alternatives are evaluated to determine their efficacy in reducing the overall timeframe necessary to achieve remedial goals. This is accomplished herein via comparison to the Monitored Natural Attenuation (MNA) remedy previously developed, evaluated, and recommended in the FFS. The remainder of this FFSA is organized as follows:

- Section 2 provides a description of the additional alternatives;
- Section 3 presents a summary of the evaluation of the alternatives;
- Section 4 provides conclusions and recommendations; and,
- Section 5 lists historical documents referenced in this FFSA.

2.0 DESCRIPTION OF ADDITIONAL REMEDIAL ALTERNATIVES

This Section briefly describes the two potential remedial alternatives developed as a result of discussions between USEPA (Region 6 and Headquarters), TCEQ, and Beazer. The alternatives are applicable for the North Area of the site (Figure 1-2) only and are as follows:

- ISCO for the Shallow Zone, the Intermediate Aquitard, and the Intermediate Zone
- ISSS for the Shallow Zone, the Intermediate Aquitard, and the Intermediate Zone

Detailed descriptions of the Site geology are provided in previous documents. In general, the Shallow Zone is fine-grained sand and silt which extends from the ground surface to approximately 20 feet below ground surface (bgs). The Shallow Zone is underlain by the Intermediate Aquitard which consists of fine-grained, interbedded, silts and clays extending from approximately 20-50 feet bgs. The Intermediate Aquitard is underlain by the Intermediate Zone, which is discontinuous across the site and consists of fine-grained sand and silt extending from approximately 50-60 feet bgs where it exists. Residual DNAPL has been identified in each of these zones in the North Area of the Site. However, given current land use considerations, particularly in the sourthern part of the Site, remedies for the shallow zone source materials were evaluated in the final FFS Report. To maintain consistency with the FFS, this has FFSA focused on the shallow zone source materials in the North Area. However, ISCO and ISSS for all three geologic zones was also evaluated from a cost perspective. Iinformation regarding the costs of ISCO/ISSS for all three geologic zones are provided in Appendix E.

2.1 ALTERNATIVE 5 – NORTH AREA ISCO

Under this alternative, soils exhibiting the presence of potential source materials (i.e., DNAPL) would be treated via ISCO. ISCO is in general a technology designed to destroy and/or immobilize organic chemicals in groundwater. For coal tar/creosote-related constituents, ISCO has been specifically developed as a remedy to immobilize free phase DNAPL source materials through development of a weathered outer skin, often referred to as in-situ bio-geochemical stabilization (ISBS). Technical information regarding this technology can be found online at

<http://www.adventusgroup.com/products/isbs.shtml>. The ISBS process option results in a reduced mass flux of dissolved phase constituents through a combination of reduced aquifer permeability, reduced mass transfer of constituents into groundwater (as a result of the "skin" effects), and temporary accelerated biodegradation of constituents in groundwater as a result of the increased dissolved oxygen concentration following injection. No significant reduction in DNAPL mass is anticipated as a result of the ISBS type injection.

Alternatively, ISCO can be employed as a direct oxidation approach aimed at destruction of organic constituents. Compared to the ISBS option discussed above, effective direct oxidation requires more aggressive oxidants delivered at higher dosages. Direct oxidation also typically requires dissolution of separate phase DNAPL into groundwater to be effective. These requirements result in a remedy that is difficult to implement as shown by numerous pilot studies. More aggressive oxidants suffer from short half-lives which make effective distribution through the aquifer problematic. Such a remedy may also typically require the addition of surfactants or co-solvents to dissolve separate phase DNAPL into the aquifer to make them available for oxidation. This is difficult to accomplish in tight geologic formations and also can results in significant degradation of groundwater quality if adequate controls cannot be assured.

It should be noted that all oxidation processes when applied to coal tar based DNAPLs tend to produce some surfactant-like effects through the partial oxidation of Polynuclear Aromatic Hydrocarbons (PAHs) and related constituents, potentially temporarily increasing the dissolved phase concentration of some constituents, particularly naphthalene (Gryzenia, et. al., 2009). Therefore, for the purpose of this evaluation, the ISBS approach will be the primary option considered while the direct oxidation approach will be considered as a secondary option.

The ISCO process relies on the delivery of chemical oxidants to affected media via injection wells, Geoprobe® injections, soil mixing, or similar methods. Although lateral distribution is problematic in tight formations using any of the preceding technologies, it has been assumed that Geoprobe® injection will be suitable for the South Cavalcade Site. The Geoprobe® injection spacing is dependent on the permeability and dispersion characteristics of the target zone.

For this Site, the Shallow Zone would likely require injections on 15 foot center spacings at most. Radius of influence testing would be required to refine this distance prior to field implementation, but this assumption hasserved as the basis for estimating costs. Also, for cost estimating purposes, it has been assumed that chemical oxidants will be delivered to the Shallow Zone from an interval of 0-20 feet below ground surface (bgs). The costs estimates provided in Appendix E include a full-depth ISCO alternative which consists of treatment of the shallow, intermediate aquitard, and intermediate zones. Denser spacing is required to implement the ISCO alternative for all three geologic formations.

2.2 ALTERNATIVE 6 – NORTH AREA ISSS

Under this alternative, soils exhibiting the presence of potential source materials (i.e., DNAPL) would be treated via in-situ solidification/stabilization (ISSS). Implementation of the ISSS remedy would limit the leaching of constituents from potential source materials into groundwater and would reduce the permeability of the soil matrix to limit contact between groundwater and impacted soils.

The ISSS process involves the mechanical mixing of reagents into the soils using equipment such as a backhoe, excavator, rotary mixer, or large diameter auger. The primary ISSS reagent(s) and application rate would be determined during a bench scale treatability study, which would be conducted during the remedial design. A typical mix design would evaluate combinations of Portland cement, cement kiln dust, various locally available industrial by-product ashes, and bentonite. The mix options would be tested at various dosages and combinations and evaluated based on remedial design goals including permeability, long term compatibility, and strength. For the purpose of this evaluation, typical stabilization agent costs have been included assuming a reasonably effective mix would be identified should the alternative move forward to design.

In the Shallow Zone, ISSS would be implemented to a depth of 20 feet bgs. Once completed, the Site would be re-graded and sloped to promote positive drainage. As with the ISCO alternative, a full depth ISSS alternative which would address the shallow, intermediation aquitard, and intermediate zones was also evaluated. Costing information for this expanded alternative is provided in Appendix E which is based on solidification/stabilization to 50 feet bgs in the Intermediate Aquitard, and to 60 feet bgs in the Intermediate Zone.

3.0 ANALYSIS OF ADDITIONAL REMEDIAL ALTERNATIVES

The additional alternatives identified in Section 2.0 are evaluated in this section based on the nine evaluation criteria established under §300.430(e)(9)(iii) of the NCP such that the potential use of the alternatives as a means to reduce the time to achieve remedial goals (versus NA) can be assessed. In addition, the efficacy of each of the alternatives versus the recommended alternative provided in the FFS report is also discussed where applicable. The nine evaluation criteria are as follows:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs
- Long-term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, and Volume
- Short-term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

Discussions of the two additional alternatives versus these evaluation criteria are discussed in the nine subsections that follow (i.e., Sections 3.1 through 3.9).

3.1 Overall Protection of Human Health and the Environment

In-Situ Chemical Oxidation - The current alternative is considered protective of human health and the environment contingent upon the assumption that land and water uses do not change at the Site. However, if the ISBS approach to the ISCO alternative is implemented (or if direct oxidation is conducted), a short-term increase in risk will be manifest due to the handling the mass quantities of reactive oxidants and potentially high pressures associated with injecting the oxidants into the subsurface. Short term risks to the environment under current conditions are not anticipated, although increased concentrations of some constituents (primarily naphthalene) would likely occur as a result of the aforementioned surfactant effects. Long term protection of human health and the environment are expected to be similar to the MNA remedy. Potential worker exposures during concrete removal and solidification would be controlled via conformance to an appropriate Health and Safety Plan and Air Monitoring Plan.

***In-Situ Solidification/Stabilization* –** Portions of the North Area are capped with concrete and this cover serves to preclude potential exposure to source materials as well as to preclude leaching of constituents from potential source areas. Implementation of an in-situ solidification alternative would necessarily involve removal of this existing concrete cover and adjoining surface soils, resulting in a short term increase in potential exposure to site constituents. Also, heavy equipment is required to implement ISSS, which presents physical hazards to workers for the construction phase. Nonetheless, this method would be protective of human health and the environment in the longer term as a result of the immobilization of the constituents of interest. Long term protection of human health and the environment are expected to be similar to the MNA remedy. Potential worker exposures during concrete removal and solidification would be controlled via conformance to an appropriate Health and Safety Plan and Air Monitoring Plan.

3.2 Compliance with ARARs

***In-Situ Chemical Oxidation* –** Underground Injection Control permitting, or equivalent controls under CERCLA would be required along with well permits. Also, the purchase, management and use of large volumes of potent oxidizing chemicals will likely require registration with, and tracking and reporting to, the Department of Homeland Security. Over the long term, in-situ treatment of source materials via ISBS is expected to reduce the localized impact to groundwater. Coupled with groundwater monitoring, this alternative is expected to comply with ARARs over the long term.

***In-Situ Solidification/Stabilization* –** Underground Injection Control permitting and well permitting would not be required for the ISSS alternative given that a solidifying agent rather than liquids is used and a different delivery method is used. Over the long term, in-situ treatment of source materials via ISSS is expected to reduce the localized impact to groundwater. Coupled with groundwater monitoring, this alternative is expected to comply with ARARs over the long term.

3.3 Long-term Effectiveness and Permanence

***In-Situ Chemical Oxidation* –** With the ISBS version of ISCO, an outer weathered skin is created around the DNAPL which immobilizes the more soluble constituents and reduces the flux of constituents from potential source areas into the groundwater as a dissolved phase. However, the ability of the weathered skin to maintain itself over long periods of time is currently unknown. If the skin is degraded over time, the immobilizing effectiveness of ISBS can be compromised.

It is considered likely that an extended period of time would be required to achieve compliance with remedial goals if an ISBS remedy is employed (in contrast to the MNA alternative). This remedy relies in part on the reduction of permeability in the treated zones to reduce mass flux of constituents. This reduction in permeability would serve to reduce the mass flux of electron acceptors capable of supporting NA bio-processes into the target zone. The combined effect of reduced mass flux of constituents from the source zones and reduced NA bio-processes within the source zone could result in an increased overall timeframe to achieve remedial goals throughout the source zone. Given that mass flux and permeability will be reduced, it is possible that a shorter period of time would be required to reach remedial goals at downgradient locations. However, this may provide limited benefit given the fact that the plume is already attenuated before it crosses the planned toll road right-of-way.

The direct oxidation option would result in a greater mass fraction of constituents being removed from the source materials initially, however the long term reduction in permeability associated with direct oxidation ISCO remedies could still result in a longer overall time to achieve remedial goals in the source zone. A significant limiting factor is the difficulty in successfully oxidizing coal tar-based free phase DNAPLs on a scale similar to that required for the South Cavalcade Site, for which no examples of successful application are known to exist.

***In-Situ Solidification/Stabilization* -** In-situ solidification will immobilize Site constituents to a large extent and, therefore, this alternative should be effective in reducing the mass flux of constituents from the source zone over the long-term. The reduction in permeability would also result in a reduction in the mass flux of electron acceptors into the source zone, which combined with the reduction in mass flux of constituents away from the source areas could increase the time to achieve remedial goals in proximity to the source zone compared to the proposed MNA remedy. Again, given that mass flux and permeability will be reduced, it is possible that a shorter period of time may be required to reach remedial goals at downgradient locations. However, this may provide limited benefit given the fact that the plume is already attenuated before it crosses the planned toll road right-of-way.

3.4 Reduction of Toxicity, Mobility, and Volume

***In-Situ Chemical Oxidation* -** The ISBS process option relies on a significant reduction in the mobility of the constituents, while the ISCO process (direct oxidation) relies primarily on the reduction in volume of constituents through chemical destruction. The ISBS process option has been proven successful in reducing constituent mobility at least in the short term, while ISCO has not been proven successful for coal tar DNAPL or source material.

***In-Situ Solidification/Stabilization* –** ISSS will significantly reduce the mobility of constituents associated with the DNAPL as a result of a combination of chemical and physical processes. The mobility of the constituents will be reduced via stabilization and the permeability of the formation will be reduced which will further reduce the potential for mobilization. No reductions in toxicity or volume are anticipated.

3.5 Short-term Effectiveness

In-Situ Chemical Oxidation – Implementation of ISBS may result in a short term increase in constituent concentrations in groundwater. However, decreases in aquifer permeability would occur rapidly with this option, possibly countering potential negative effects associated with increased constituent concentrations. As there are no short-term risks associated with the target area, this alternative is considered to have adequate short-term effectiveness.

***In-Situ Solidification/Stabilization* -** In the short-term, ISSS could reduce mobility of constituents and effectively counter the negative effects of destruction of existing cap areas. As there are no short-term risks associated with the target area, this alternative is considered to have adequate short-term effectiveness

3.6 Implementability

In-Situ Chemical Oxidation – The ISBS alternative can be readily implemented, although the large volume of oxidants required will require careful planning and logistics, and may also require registration and tracking mandated by the Department of Homeland Security. In-situ chemical oxidation treatments are relatively easy to implement and can be conducted in a short time period. However, if a tenant were to occupy the property prior to the implementation of the remedy (which will require bench- and pilot-scale studies), interference with their operations could occur over the short term.

***In-Situ Solidification/Stabilization* -** In-situ stabilization of the scale included in this alternative will require large construction equipment including excavators and large diameter auger rig(s) to implement. Nonetheless, this alternative relies on proven technologies using readily available equipment and could be implemented readily at the Site. Again, if a tenant were to occupy the property prior to the implementation of the remedy (which will also require bench- and pilot-scale studies), interference with their operations could occur over the short term.

3.7 Cost

Capital, annual, and present worth costs of each of the alternatives are provided in the tables included as Appendix E. Brief descriptions of the capital, operation and maintenance, and present worth costs for each of the additional alternatives follow.

In-Situ Chemical Oxidation - The capital cost of implementation of the ISBS version of the ISCO alternative for the shallow zone North Area soils is $4,600,275. The operation and maintenance costs associated with this alternative are $77,000 per year. The present worth of this alternative is approximately $6,079,873. The cost of completing a comparable direct oxidation remedy would be greater by a considerable factor.

***In-Situ Solidification/Stabilization* - T**he capital cost of implementation of the ISSS alternative for the shallow zone North Area soils is $5,749,050. The operation and maintenance costs associated with this alternative are $77,000 per year. Therefore, the present worth of this alternative is approximately $7,228,648. This estimate is based on the assumption that stabilization can be completed at targeted depths and that stabilization of the entire soil column from the ground surface to the target depth need not be completed.

3.8 State Acceptance

The evaluation of this criterion cannot be finalized until the TCEQ has reviewed and commented upon this FFSA. However, for the purposes of this evaluation, it is assumed that both alternatives will be acceptable to the TCEQ.

3.9 Community Acceptance

The evaluation of this criterion cannot be finalized until the public has reviewed and commented upon the Proposed Plan. Nevertheless, information relevant to the public evaluation of the remedial alternatives is summarized herein.

***In-Situ Chemical Oxidation* -** Implementation of the ISBS alternative does not currently pose any community acceptance issues although some objection to the use of hazardous oxidants may arise as a community relations issue.

In-Situ Solidification/Stabilization - It is possible that the community of business owners occupying the other property areas would oppose the in-situ stabilization alternative. ISSS could have a significant negative impact on nearby business operations even with appropriate controls given the high volume of traffic necessary to implement such a remedy and the large equipment used to complete the stabilization/solidification process.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This section provides a brief summary of the conclusions and recommedations developed as a result of consideration of the four alternatives evaluated in the final FFS and the two alternatives evaluated in this FFSA.

4.1 CONCLUSIONS

Approximately 10 years of operational data, and almost 20 years of analytical data have been considered in support of the FFS and FFSA. In addition, regulatory guidance and ARARs were considered during the data review process and remedial alternative evaluation. The major conclusions reached as a result of this review process are as follows:

- No evidence of continuing DNAPL migration through the natural subsurface or via potential preferential pathways has been identified at the Site during extensive studies of potential migration pathways;

- Dissolved constituent distributions at the Site have been shown to be consistent with natural attenuation – concentrations of dissolved phase constituents have not increased across the Site, particularly in down-gradient locations;

- Groundwater pumping and treatment has not impacted Site plumes in light of the limited area of influence of the pumping wells. Consequently, observed reductions in Site plumes are attributable to alternate processes;

- The reductions in dissolved phase COI concentrations and the spatial distribution of parameters indicative of biological activity suggest that natural attenuation mechanisms are primarily responsible for the observed declines in COI concentrations at the Site;

- Groundwater pumping has not resulted in appreciable mobilization of DNAPL at the Site; the majority of the DNAPL appears to exist as residual DNAPL rather than as free product that can be readily recovered;

- In spite of over 10 years of pumping operations from recovery wells which are optimally located for recovery of DNAPL, less than 4,000 gallons of DNAPL have been recovered and it has been estimated that less than 2 percent of the DNAPL present at the Site has been removed;

- Given that less than 2% of the DNAPL has been recovered in approximately 10 years, almost 500 years of additional pumping would be necessary to remove the remaining material if it were recoverable and assuming DNAPL recovery rates ceased their declining trend;

- The operating data for the pump and treat and DNAPL recovery system clearly demonstrate the technical impracticability of recovering DNAPL at the Site;

- No known groundwater exposure pathways currently exist at the Site as a result of surrounding land and water use, the absence of migration pathways, the natural attenuation that is evident at the Site, and as a result of institutional controls in place for the Site itself; and,

- Future groundwater use in the vicinity of the Site is unlikely and mechanisms are available to ascertain if this condition changes in the future. Institutional controls will be used to prohibit future groundwater use within the TI Zones.

Based on the conceptual understanding of existing Site conditions, and as a result of continued discussions between Beazer, USEPA, and TCEQ, a subset of potentially viable remedial alternatives were identified for the Site. These alternatives consisted of the following:

- Alternative 1 - No Further Action
- Alternative 2 – MNA with No Further Source Zone Action
- Alternative 3 - MNA with Continued Source Removal
- Alternative 4 - ISSS of Readily Accessible Source Materials
- Alternative 5 – North Area ISCO of Shallow Source Materials
- Alternative 6 – North Area ISSS of Shallow Source Materials

Alternatives 1 through 4 were evaluated in the final FFS while alternatives 5 and 6 were evaluated in this FFSA. These alternatives were evaluated in accordance with the requirements specified in the National Contingency Plan. Each alternative was considered versus the nine criteria applicable for remedial alternative evaluation. Table 4-1 provides a brief summary of the results of the remedial alternative evaluation process for all six alternatives. Table 4-2 provides a cost estimate summary for all six alternatives.

In addition to the observations provided in the FFS, observations are also provided with respect to the specific alternatives discussed in this FFSA (i.e., ISCO [as ISBS] for North Area shallow zone source materials and ISSS for North Area shallow zone source materials), The USEPA's goal for the implementation of either of these additional remedies is to significantly reduce the amount of time necessary to reach remedial goals compared to the MNA alternative discussed in the final FSS.

The ISBS alternative (Alternative 5) presents a challenge in the overall protection of human health and environment, short-term effectiveness, long-term effectiveness, state acceptance and cost categories. Potential health risks exist as a result of worker safety when handling the mass quantities of reactive oxidants and high pressures associated with injecting the oxidants into the subsurface. In the short-term, ISBS will reduce aquifer permeability and may initially cause an increase in dissolved phase constituent concentrations. The effectiveness of ISBS is also limited as a result of the potential lack of permanence of the weathered skin effects responsible for some of the alternatives effectiveness. The ISBS alternative is not expected to significantly reduce the amount of time required to achieve remedial goals as a result of the reduced rate of degradation via natural attenuation mechanisms and may actualy result in an increase of the time needed to achieve remedial goals in proximity to the source zone. The limited benefits of this alternative do not justify the high costs. This ISBS alternative is substantially more costly than the preferred alternative identified in the Final FFS (i.e., MNA), provides no short or long term reduction in risk, and does not achieve remedial goals in a more timely fashion than MNA alone.

The ISSS alternative (Alternative 6) presents challenges in the categories of implementability, community acceptance, long-term effectiveness, and cost. As previously shown on Figure 1-2, a large area of solidification/stabilization area is envisioned for this alternative. A great deal of large construction equipment and ancillary support equipment such as hoppers would be necessary to implement this alternative. Large quantities of stabilizing agents would be necessary resulting in a great deal of overland traffic. Consequently, the possibility of community concerns may exist, particularly if the Site is occupied prior to remediation. A similar alternative was implemented on a much smaller scale at the North Cavalcade Site and apparently these issues were adequately addressed. However, a treatment volume of approximately 56,000 cubic yards (CY) is estimated for the dispersed residual DNAPL in the shallow zone at the South Cavalcade Site, whereas 12,000 CY were treated at the North Cavalcade Site. Implementation of this alternative is not expected to significantly reduce the amount of time required to reach remedial goals compared to the MNA alternative. This alternative is substantially more costly than the preferred alternative identified in the Final FFS.

Based on review of the information in Section 3.0, it is evident that both of the alternatives are very high in cost and will not significantly reduce the amount of time necessary to reach remedial goals throughout the Site versus the MNA Alternative. Therefore, ISBS or ISSS alternatives are not recommended as solutions to achieve EPA's goals.

4.2 RECOMMENDATIONS

Based on review of the summary information provided in Table 4-1, it is evident that each of the alternatives, including the No Further Action alternative, is considered protective of human health and the environment. The primary discriminating factors between the various alternatives are the following:

- Compliance with ARARs
- Community Acceptance
- State Acceptance
- Cost

The No Further Action alternative is not considered entirely compliant with ARARs because it includes no provisions for monitoring as suggested by the TRRP. Consequently, State acceptance of this alternative may be difficult to obtain. The use of a disruptive alternative (i.e., Site-wide in-situ solidification/stabilization) is expected to objectionable to community business owners and others at and in the vicinity of the Site. Alternatives 5 (ISBS) and 6 (ISSS) which focus on the North Area alone have numerous associated challenges as discussed in the previous section, are quite costly (Table 4-2), offer little or no benefit from a risk-reduction perspective, and will not significantly reduce the amount of time to achieve remedial goals. By contrast, no major shortcomings can be identified for Alternatives 2 or 3. Both of these alternatives are expected to provide for continued protection of human health and the environment.

The major difference between these alternatives is associated with the cost criterion of the NCP. The MNA with Continued Source Removal alternative is approximately 7 times more expensive than the MNA with No Further Action for Source Zone alternative. The cost disparity between these two alternatives is an over-riding discriminator given that source control measures implemented over the last decade have been shown to be of no benefit at the Site.

Consequently, it is recommended that Alternative 2 still be pursued as the preferred alternative for the Site. It is further recommended that the scope of the MNA program be developed during the design process through continued discussions between Beazer, the USEPA, and the TCEQ. A TI Demonstration Report has been prepared on behalf of Beazer to present the justification that a TI Waiver is necessary for amendment of the ROD to select an MNA remedy. It is also recommended that institutional controls be established to prohibit the future use of groundwater within the TI Zones.

5.0 REFERENCES

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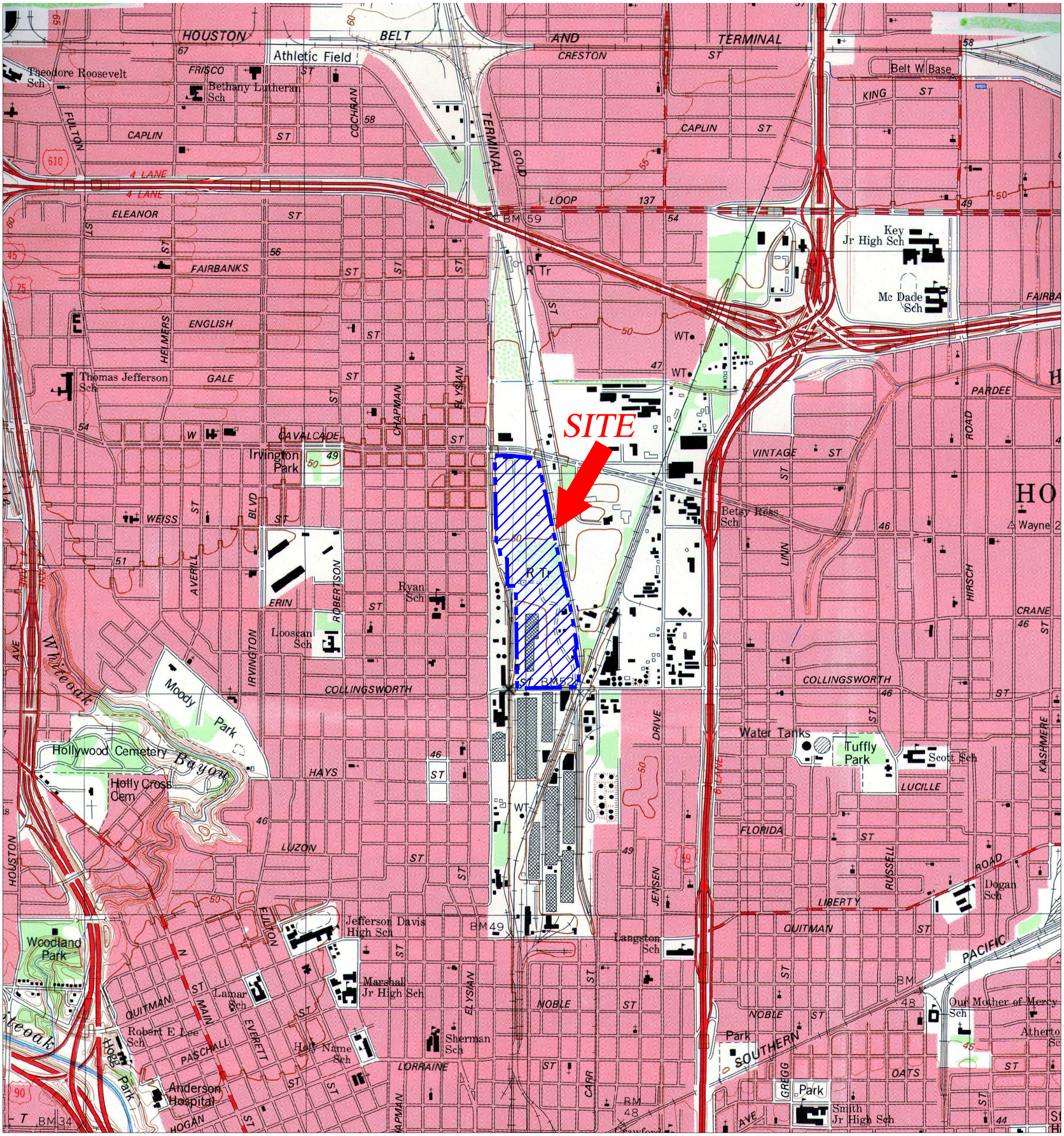
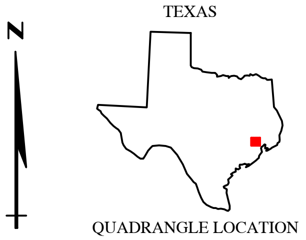
KEY (Key Environmental, Inc.), March 30, 2011. Evaluation of Natural Attenuation – South Cavalcade Superfund Site – Houston, Texas. Pittsburgh, PA.

FIGURES





REFERENCE: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE OF SETTEGAST, TEXAS – 1982

ISSUE DATE:

KEY ENVIRONMENTAL, INC.
200 THIRD AVENUE
CARNEGIE, PA 15106

BEAZER EAST, INC
PITTSBURGH, PENNSYLVANIA

DRWN: TDD	DATE: 03/02/12
CHKD: RJH	DATE: 03/02/12
APPD: JSZ	DATE: 03/02/12
SCALE:	1" = 2000'

KEY ENVIRONMENTAL INCORPORATED

FOCUSED FEASIBILITY STUDY ADDENDUM
ISCO TECHNOLOGY ALTERNATIVE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

SITE LOCATION MAP

PROJECT NO: 11-233

FIGURE 1-1

y:\south cavalcade\11-318\focused feasibility study addendum isco technolofy alternative\figure 1-1.dwg Last Saved By: Scomer 3/8/2012 12:51 PM Plotted By: Shelly Comer 4/19/2012 11:16 AM Scale: 1:1

006321

LEGEND

- SITE BOUNDARY
- PROPERTY BOUNDARIES
- PROPOSED HARDY TOLL ROAD EXTENSION RIGHT-OF-WAY
- AREAS COVERED WITH ASPHALT OR CONCRETE
- CONCRETE CAP CONSTRUCTED BY BEAZER
- INFERRED EXTENT OF DNAPL (SEE NOTE 1)

NOTE:

1. POTENTIAL DNAPL SOURCE AREA IN SHALLOW AQUIFER BASED ON VISUAL OBSERVATION, MEASURED DNAPL IN MONITORING WELLS, TOTAL PAH CONCENTRATIONS > 100 MG/KG, OR SURROGATE TOTAL AROMATIC HYDROCARBON CONVENTRATIONS > 1,000 MG/KG.

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRWN: TDD	DATE: 03/02/12	KEY ENVIRONMENTAL INCORPORATED
CHKD: RJH	DATE: 03/02/12	
APPD: JSZ	DATE: 03/02/12	
SCALE: AS SHOWN		

FOCUSED FEASIBILITY STUDY ADDENDUM
ISCO TECHNOLOGY ALTERNATIVE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

GENERAL SITE ARRANGEMENT AND NORTH AREA SHALLOW ZONE INFERRED DNAPL EXTENT

PROJECT NO: 11-318

FIGURE 1-2

REV #	DATE	DESCRIPTION	APPD
△			
△			
△			

REFERENCE: PROPOSED HARDY TOLL ROAD EXTENSION RIGHT-OF-WAY BASED ON HARDY CONNECTOR SCHEMATIC - FROM: US59/IHIO INTERCHANGE TO: HARDY TOLL ROAD/IHIO610 INTERCHANGE, DANNENBAUM ENGINEERING CORPORATION, 07/24/2009.

ISSUE DATE:

KEY ENVIRONMENTAL, INC.
200 THIRD AVENUE
CARNEGIE, PA 15106

y:\south cavalcade\11-318\focused feasibility study addendum isco technology alternative\figure 1-2.dwg Last Saved By: Scomer 4/13/2012 2:44 PM Plotted By: Shelly Comer 4/19/2012 11:15 AM Scale: 1:1

FIGURE 1-3A - SHALLOW ZONE DNAPL EXTENT

FIGURE 1-3B - INTERMEDIATE AQUITARD DNAPL EXTENT

FIGURE 1-3C - INTERMEDIATE ZONE DNAPL EXTENT

N

LEGEND:

- SHALLOW ZONE DNAPL EXTENT (AREA = ~182,000 SF)
- INTERMEDIATE AQUITARD DNAPL EXTENT (AREA = ~232,000 SF)
- INTERMEDIATE ZONE DNAPL EXTENT (AREA = ~166,000 SF)
- OFFICE BUILDING, SHOP, WAREHOUSE, OR MAINTENANCE BAY
- LATERAL EXTENT OF DNAPL

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRWN: TDD	DATE: 03/02/12
CHKD: RJH	DATE: 03/02/12
APPD: JSZ	DATE: 03/02/12
SCALE:	AS SHOWN

KEY ENVIRONMENTAL INCORPORATED

FOCUSED FEASIBILITY STUDY ADDENDUM
ISSS TECHNOLOGY ALTERNATIVE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

REFERENCE:

ISSUE DATE:

KEY ENVIRONMENTAL, INC.
200 THIRD AVENUE
CARNEGIE, PA 15106

INFERRED EXTENT OF DNAPL
IN THE NORTH AREA

PROJECT NO: 11-318

FIGURE 1-3

TABLES

TABLE 4-1

REMEDIAL ALTERNATIVE EVALUATION SUMMARY
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Alternative	Description	Evaluation Critieria								
		Protective of Human Health and the Evironment?	Compliant with ARARS?	Effective and Permanent over the Long-Term	Reduction of Toxicity, Mobility, or Volume	Effective over the Short-Term	Implementable?	Cost?	Acceptable to the State?	Acceptable to the Community?
1	No Further Action	Yes	No	Yes	Yes	Yes	Yes	Low	TBD[1]	TBD
2	MNA with No Further Action for Source Zone	Yes	Yes	Yes	Yes	Yes	Yes	Low	TBD	TBD
3	MNA with Continued Source Removal	Yes	Yes	Yes	Yes	Yes	Yes	High	TBD	TBD
4	In-Situ Solidification/ Stabilization[2]	Yes	Yes	Yes	Yes	Yes	Yes	High	TBD	TBD
5	North Area In-Situ Chemical Oxidation[2]	Yes	Yes	Yes	Yes	Yes	Yes	High	TBD	TBD
6	North Area In-Situ Solidification/Stabilization[2]	Yes	Yes	Yes	Yes	Yes	Yes	High	TBD	TBD

1. TBD - To Be Determined - Can not be assessed at this time.
2. Alternative 4, 5, and 6 address accessible shallow zone soils only.

TABLE 4-2

REMEDIAL ALTERNATIVE COST ESTIMATE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Alternative	Description	Capital Cost	Annual Costs[1]	Total
1	No Further Action	$207,813	$317,057	$524,869
2	MNA with No Further Action for Source Zone	$42,188	$910,154	$952,341
3	MNA with Continued Source Removal	$129,938	$5,137,578	$5,267,515
4	In-Situ Solidification/Stabilization[2]	$16,433,025	$1,479,598	$17,912,623
5	North Area In-Situ Chemical Oxidation[3]	$4,600,275	$1,479,598	$6,079,873
6	North Area In-Situ Solidification/Stablization[2,3]	$5,749,050	$1,479,598	$7,228,648

1. Present worth of annual costs based on 5% discount factor and 30-year project life.
2. In-situ Solidification/Stablization Alternatives (4 and 6) based on assumption that stabilization can be targeted at depth. This is not generally practicible - the entire soil column from the ground surface to the target depth interval must be stabilized. Costs are low-end estimates.
3. Alternatives 5 and 6 for the North Area do not include the costs of implementation of the MNA alternative for the South Area. Cost estimates for these alternatives for shallow zone soils only.
   Costs for North Area ISCO and ISSS across all three geologic zones are provided in Appendix E. The cost to conduct in-situ chemical oxidation or in-situ solidifcation/stabilization for all three zones in the north area are approximately $16.8M and $15.4M, respectively.

APPENDICES

APPENDIX A

APPENDIX A
SOURCE CONTROL (DNAPL) TECHNOLOGY SCREENING SUMMARY
FOCUSED FEASIBILITY STUDY - SOUTH CAVALCADE SITE - HOUSTON, TX

General Response Action	Remedial Technology	Process Options	Technology Description	Evaluation Criteria[1]			Advantages	Limitations	Retain or Eliminate
				Effectiveness	Implementability	Cost			
In-Situ Treatment	In-Situ Thermal Treatment	Resistance Heating (3- or 6-Phase)	Use multiple electrode arrays and multiphase electricity (up to 12 phase) to heat soil via resistivity heating. Collect offgases and mobilized DNAPL via SVE system/recovery wells.	Effective	Not Implementable	High ($80-$120/CY)	Potential reduction in mobility and volume under ideal circumstances.	Electrical conductivity of subsurface may adversely affect performance. Extensive above ground equipment is infeasible for active facility. Stray electrical currents can present a physical health hazard to workers.	
		Steam Injection	Inject boiler-generated steam into the subsurface under pressure to mobilize trapped DNAPL. Collect offgases and mobilized DNAPL via SVE system/recovery wells.	Effective	Not Implementable	High ($80-$120/CY)	Potential reduction in mobility and volume.	Typically applied for sandy media. No demonstrated success for creosote sites. Extensive above ground equipment is infeasible for an active facility. Steam hazards may also exist for active facility. Thermal methods may kill soil microbes.	
		Conductive Heating (ISTD)	Installation of conductive heating elements to raise groundwater temperature well above boiling point. Collect gases and mobilized DNAPL via SVE system/recovery wells.	Effective	Not Implementable	High ($80-$120/CY)	Potential reduction in mobility and volume, and potentially applicable for layered impermeable strata.	Thermal conductivity of media may adversely affect performance. Extensive above ground equipment is infeasible for an active facility. Steam hazards may exist for an active facility given high temperature attained.	
		In-Situ Vitrification (ISV)	Use of graphite electrodes and high voltage to vitrify soil via temperatures ranging to approximately 1,600 ^{o}C (i.e., melt the soil media). Macroencapsulate metals and destroy organics.	Effective	Not Implementable	High ($80-$120/CY)	Macroencapsulation in a vitrified mass or hydrocarbon destruction occurs.	Extreme temperatures required to melt soil. Cannot reasonably be implemented at an active facility. Potential effects on adjacent properties as a result of water table elevation and effects on groundwater flow direction.	
		Radio-Frequency Heating	Employ antennae to supply EM energy in the RF band to heat nonconductive materials and mobilize DNAPL. Collect gases and mobilized DNAPL via SVE system/recovery wells.	Effective	Not Implementable	High ($80-$120/CY)	Applicable in dense stratified formations. Potential reduction in volume.	Extensive above ground equipment is infeasible for active facility. Perimeter controls required given potential for uncontrolled migration. Demonstrated for chlorinated solvents but not for coal tar-related DNAPLs.	

General Response Action	Remedial Technology	Process Options	Technology Description	Evaluation Criteria[1]			Advantages	Limitations	Retain or Eliminate
				Effectiveness	Implementability	Cost			
In-Situ Treatment (Cont'd)	In-Situ Physical Chemical Treatment	Water Flooding (with or without Surfactants)[2]	Injection of water (w or w/o surfactants) to increase recovery of non-aqueous phase liquids as a result of increased solubility and/or hydrodynamic forces.	Effective	Not Implementable	Moderate ($40-$80/CY)	May reduce volume under ideal conditions.	Delivery is unachievable for sites where water cannot be added as a result of low permeability. May only improve DNAPL dissolution. Long operating times are likely for recalcitrant product. Perimeter control required. Not developed for free phase DNAPL.	
		Solvent Injection	Injection of co-solvents (e.g., alcohols) to increase constituent solubility and mobilize residual DNAPL for subsequent removal using recovery wells.	Effective	Not Implementable	Moderate ($40-$80/CY)	May reduce volume under ideal conditions.	Delivery is unachievable for sites where solvent cannot be added as a result of low permeability. May only improve dissolution of DNAPL. Long operating times are likely for recalcitrant product. Perimeter control required. Not developed for free phase DNAPL.	
		Chemical Oxidation	Injection of oxidants such as permanganate, persulfate, or Fenton's Reagent to completely oxidize organics to water and carbon dioxide.	Effective	Not Implementable	Moderate ($40-$80/CY)	Can result in the complete destruction of organics and DNAPL.	Soil reaction is the primary driver for oxidant demand. Targeted delivery is difficult and delivery is unachievable for sites where oxidant cannot be added as a result of low permeability. Oxidizing agents can be pose safety and human health hazards.	
		Chemical Reduction	Introduction of reducing agents such as molasses, lactate, or vegetable oils for reductive dechlorination (or addition or inorganic species to reduce valence states of metals (e.g., Cr+6)	Ineffective	Not Implementable	Moderate ($40-$80/CY)	Can result in reduction of volume and toxicity.	Primarily applicable for metals or chlorinated solvents (dechlorination). No known applications for creosote. Targeted delivery is difficult and delivery is unachievable for sites where agent cannot be added as a result of low permeability.	

APPENDIX A
SOURCE CONTROL (DNAPL) TECHNOLOGY SCREENING SUMMARY
FOCUSED FEASIBILITY STUDY - SOUTH CAVALCADE SITE - HOUSTON, TX

General Response Action	Remedial Technology	Process Options	Technology Description	Evaluation Criteria[1]			Advantages	Limitations	Retain or Eliminate
				Effectiveness	Implementability	Cost			
In-Situ Treatment (Cont'd)	In-Situ Physical Chemical Treatment (Cont'd)	Polymer Injection	Similar to surfactant flushing or flooding. Polymer(s) are used to decrease interfacial tension and hence to mobilize residual DNAPL.	Effective	Not Implementable	Moderate ($40-$80/CY)	May reduce volume under ideal conditions.	Delivery is unachievable for sites where solvent cannot be added as a result of low permeability. May only improve dissolution rates of DNAPL. Long operating times are likely for recalcitrant product. Perimeter control required. Not developed for free phase DNAPL.	
		Stabilization/ Solidification	Injection of grout to reduce the permeability of the formation to reduce dissolution and to physically macroencapsulate DNAPL.	Effective	Not Implementable	Moderate ($40-$80/CY)	Can result in reduction of mobility.	Detailed information on target zones is required. May adversely affect groundwater flow conditions and cause ponding. Increases volume. May adversely affect foundations and paved areas (heaving). Implementation at an active facility is not feasible.	
		Biogeochemical Stabilization	Addition of modified oxidants to cause surficial weathering of DNAPL such that mobile components are destroyed and residual components are immobilized.	Effective	Not Implementable	Moderate ($40-$80/CY)	Can result in reduction of mobility.	Detailed information on target zones is required. Delivery is unachievable for sites where modified oxidants cannot be added as a result of low permeability. Implementation at an active facility is not feasible.	
	In-Situ Biological Treatment	Air-Sparging and Vapor Extraction	Injection of air into aquifer to promote outgassing (and possibly biodegradation) and recovery of volatiles from unsaturated zone via vacuum extraction.	Ineffective	Not Implementable	High ($80-$120/CY)	Can result in reduction of toxicity.	Primarily applicable for VOCs and a few SVOCs. Ineffective in fine grained materials and only directly addresses dissolved constituents. Not suitable to address DNAPL. Extensive above ground equipment is infeasible for an active facility with vehicular traffic.	

General Response Action	Remedial Technology	Process Options	Technology Description	Evaluation Criteria[1] Effectiveness	Implementability	Cost	Advantages	Limitations	Retain or Eliminate
In-Situ Treatment (Cont'd)	In-Situ Biological Treatment (Cont'd)	Electron Acceptor Addition	Inject oxygen, sulfate, nitrate, or other electron acceptors to enhance biodegradation via aerobic respiration or anaerobic degradation.	Ineffective	Not Implementable	Moderate ($40-$80/CY)	Technology relies on naturally-occurring microorganisms.	Only directly addresses the dissolved phase constituents. Delivery is unachievable for site where acceptors cannot be added as a result of low permeability. Long time frame to achieve remediation via multiple injections.	
		Electron Donor Addition	Introduction of reducing agents such as molasses, lactate, or vegetable oils to for reductive dechlorination (Also see Chemical Reduction, as above)	Ineffective	Not Implementable	Moderate ($40-$80/CY)	Technology relies on naturally-occurring microorganisms.	Only directly addresses the dissolved phase constituents and no known applications for creosote. Donor delivery is unachievable for sites with low permeability. Long time frame to achieve remediation via multiple injections.	
		Enhanced Bioremediation (Nutrients)	Inject nutrients such as nitrogen and/or phosphorus to enhance growth and activity of naturally-occurring microorganisms.	Ineffective	Not Implementable	Moderate ($40-$80/CY)	Technology relies on naturally-occurring microorganisms.	Only directly addresses the dissolved phase constituents. DNAPL not directly addressed. Nutrient delivery is unachievable for sites with low permeability. Long time frame to achieve remediation via multiple injections is generally required.	
		Bioslurping	Combination of bioventing and vacuum recovery of floating free product in vadose zone soils and in the capillary fringe.	Ineffective	Not Implementable	Moderate ($40-$80/CY)	Potential reduction of mobility and volume.	Degradation of organic compounds can occur. Not effective in low permeability soil. Primarily appropriate for LNAPL and vapor phase impacts. Extensive above ground equipment is infeasible for active facility. Not effective for DNAPL recovery.	

APPENDIX A
SOURCE CONTROL (DNAPL) TECHNOLOGY SCREENING SUMMARY
FOCUSED FEASIBILITY STUDY - SOUTH CAVALCADE SITE - HOUSTON, TX

General Response Action	Remedial Technology	Process Options	Technology Description	Evaluation Criteria[1]			Advantages	Limitations	Retain or Eliminate
				Effectiveness	Implementability	Cost			
In-Situ Treatment (Cont'd)	In-Situ Biological Treatment (Cont'd)	Bioventing	Induce minimal air flow in the vadose zone to provide electron acceptor (oxygen) and thereby promote aerobic biodegradation.	Ineffective	Not Implementable	Moderate ($40-$80/CY)	Potential reduction of mobility and volume.	Degradation of organic compounds can occur. Not effective in low permeability soil. Primarily appropriate for LNAPL and vapor phase impacts. Extensive above ground equipment is infeasible for active facility with vehicular traffic. Not effective for DNAPL recovery.	
		Phytoremediation	Use of plants for uptake of dissolved constituents Control of infiltration to limit leaching or hydrodynamic flow associated with high water table elevations.	Ineffective	Not Implementable	Low ($10-$30CY)	Technology is not energy intensive.	Phyto-remediation is generally used for metals recovery rather than for organics. When used for infiltration control, typically requires planting of multiple species and cannot be implemented at existing paved facility. Ineffective for DNAPL recovery/treatment.	
		Monitored Natural Attenuation	Reliance on existing site physical and naturally occurring biological phenomena to degrade/attenuate constituents.	Ineffective	Implementable	Low ($10-$30CY)	Effectiveness demonstrated at multiple sites.	Technology is not energy intensive. Only directly addresses dissolved phase constituents. Long time frame to achieve remediation of non-aqueous phase liquids. Long-term groundwater monitoring and contingency planning is necessary.	
Physical Removal	Passive Automated Recovery	DNAPL Pumping (Wells/Trenches)	Pumping of mobile DNAPL from stickup, flushmount, or horizontal wells or trenches with subsequent disposal.	Effective	Implementable	Moderate ($40-$80/CY)	Technology is proven for the recovery of DNAPL and volume reduction.	Applicable only for mobile, and not residual, DNAPL. Comparable technology (gradient-enhanced recovery) has already been implemented at the site (10 yrs) to recover mobile DNAPL with diminishing returns.	

APPENDIX A
SOURCE CONTROL (DNAPL) TECHNOLOGY SCREENING SUMMARY
FOCUSED FEASIBILITY STUDY - SOUTH CAVALCADE SITE - HOUSTON, TX

General Response Action	Remedial Technology	Process Options	Technology Description	Evaluation Criteria[1]			Advantages	Limitations	Retain or Eliminate
				Effectiveness	Implementability	Cost			
Physical Removal (Cont'd)	Gradient-Enhanced Recovery	Water/DNAPL Pumping (Wells/Trenches)	Pumping of mobile DNAPL and groundwater from stickup or flushmount recovery wells, or horizontal wells or trenches with subsequent oil/water separation and disposal.	Effective	Implementable	High ($80-$120/CY)	Technology is proven for the recovery of DNAPL and volume reduction.	Applicable only for mobile, and not residual, DNAPL. Hydrodynamic force may be insufficient to mobilize DNAPL. Has already been implemented at the site (10 yrs) to recover mobile DNAPL with diminishing returns.	
	Passive Non-Automated Recovery	DNAPL Recovery (Bailers/Pumps)	Removal of potentially mobile DNAPL via intermittent recovery from stickup or flushmount recovery wells, or horizontal wells with pumps or bailers.	Effective	Implementable	Low ($10-$30/CY)	Technology is proven for the recovery of DNAPL and volume reduction.	Applicable only for mobile, and not residual, DNAPL. Technology has already been implemented at the site to recover mobile DNAPL with diminishing returns. Optimum recovery well locations selected (EPA/TCEQ involvement).	

1. Descriptions of the relative assessments for the various screening criteria are as follows: (Observations shown in red typeface are considered grounds for elimination: cost alone is not used as the basis for elimination).

A. Effectiveness: *(Note: Effectiveness of a given technology as defined in the RI/FS guidance document related solely to the applicability of the technology, not the performance).*

i. Ineffective - Technology is not applicable given site-specific physical or geologic conditions or chemical-specific considerations.
iii. Effective - Technology is applicable given site-specific physical and geologic conditions and chemical-specific considerations.

B. Implementability: *(Note: Implementability assessment is based on current site configuration and land use. Technologies may be implementable at the facility were it vacant).*

i. Implementable - Technology can be readily implemented at the site under current land use (i.e., active trucking terminal) conditions.
ii. Not Implementable - Technology cannot be implemented under existing site conditions given substantial dispersed surface features (e.g., electrodes) or safety concerns (e.g., steam or currents).

C. Cost: *(Note: Cost assessment is relative in nature. Given site conditions and land use, only in-situ applications have been considered)*

i. Low - cost is negligible relative to other in-situ applications. Costly ex-situ alternatives such as excavation and transportation/disposal or treatment are not used for comparative purposes.
ii. Moderate - cost is in the mid-range of in-situ applications. Costly ex-situ alternatives such as excavation and transportation/disposal or treatment are not used for comparative purposes.
iii. High - cost is in the upper range of in-situ applications. Costly ex-situ alternatives such as excavation and transportation/disposal or treatment are not used for comparative purposes.

2. Beazer applications have employed water flooding. Surfactants have not been evaluated/used.

3. Phytoremediation used as a supporting technology to limit infiltration and hence maintain hydraulic control.

APPENDIX B

Project Meeting
South Cavalcade Superfund Site
Houston, Texas

December 14, 2011

Meeting Participants

Beazer East, Inc.

U.S.EPA

Texas Commission on Environmental Quality

Key Environmental, Inc.

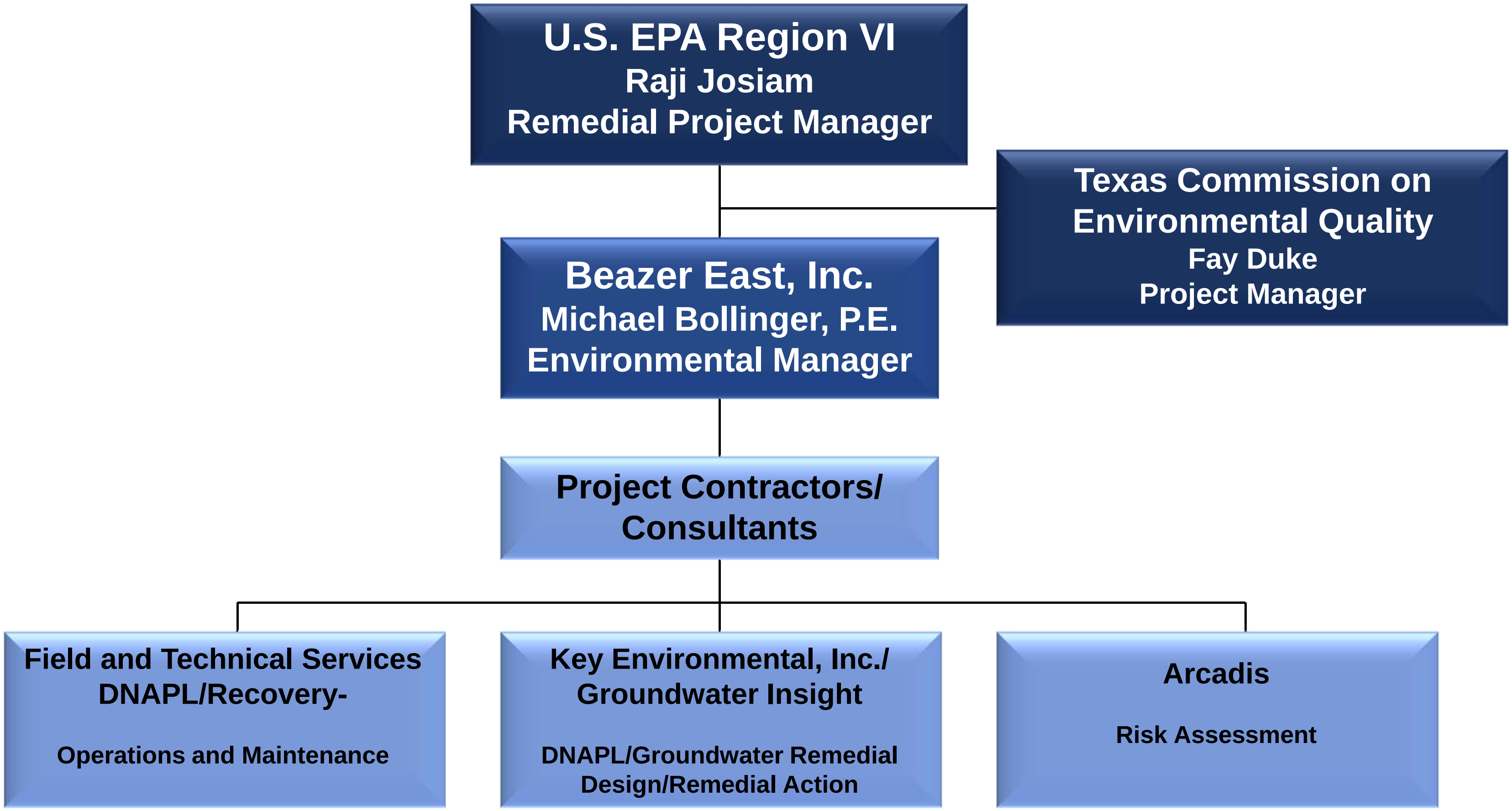
Groundwater Insight, Inc.

Presentation Outline

- Introduction
- History
- Conceptual Site Model
- DNAPL Recovery System
- Focused Feasibility Study
- Technical Impracticability Demonstration
- Evaluation of Monitored Natural Attenuation
- Screening of Additional Technologies
- Action Items and Schedule

KEY ENVIRONMENTAL INCORPORATED
Beazer

Project Organization



History

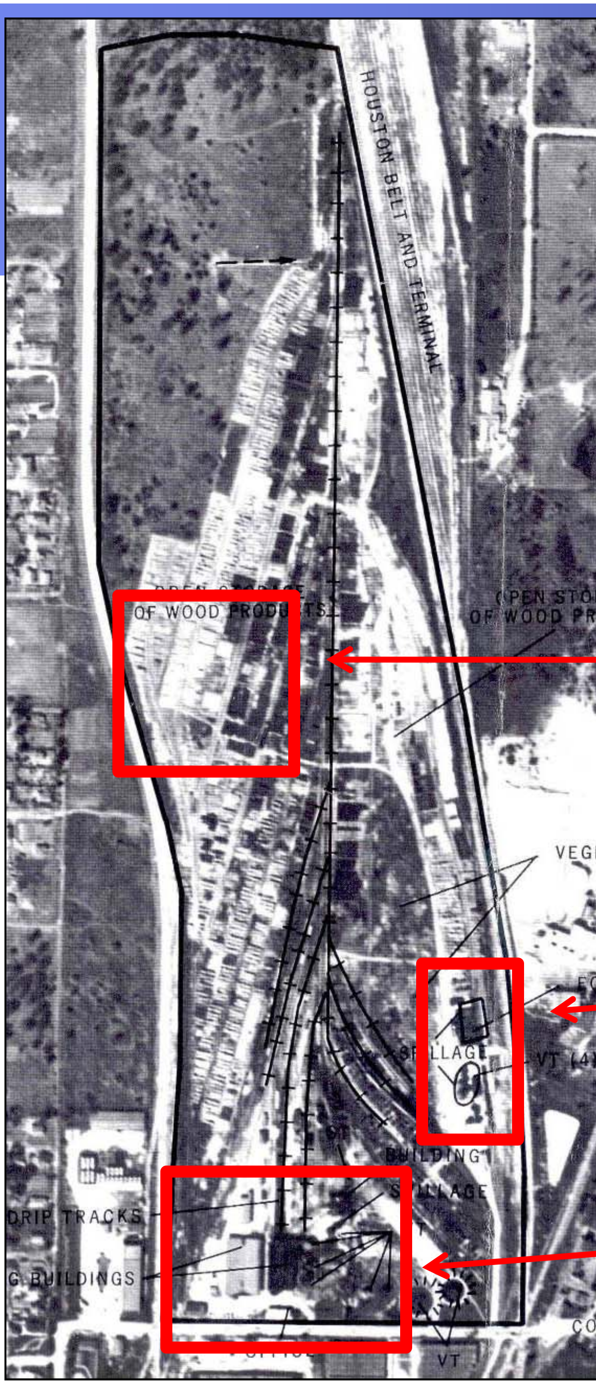
Site Operations History

- Wood Treating Conducted Using Primarily Creosote from Circa 1910 to 1962
- Coal Tar Processing Plant Operated from 1944 to 1962
- Wood Treating Plant Dismantled Following Closure (Circa 1962)
- Site Used for Non-Residential Purposes Since Closure (Primarily Trucking)
- Administrative Order on Consent (AOC) Between Property Owners and EPA Restrict Property Use

KEY ENVIRONMENTAL INCORPORATED
Beazer

History

Aerial Photograph - 1944



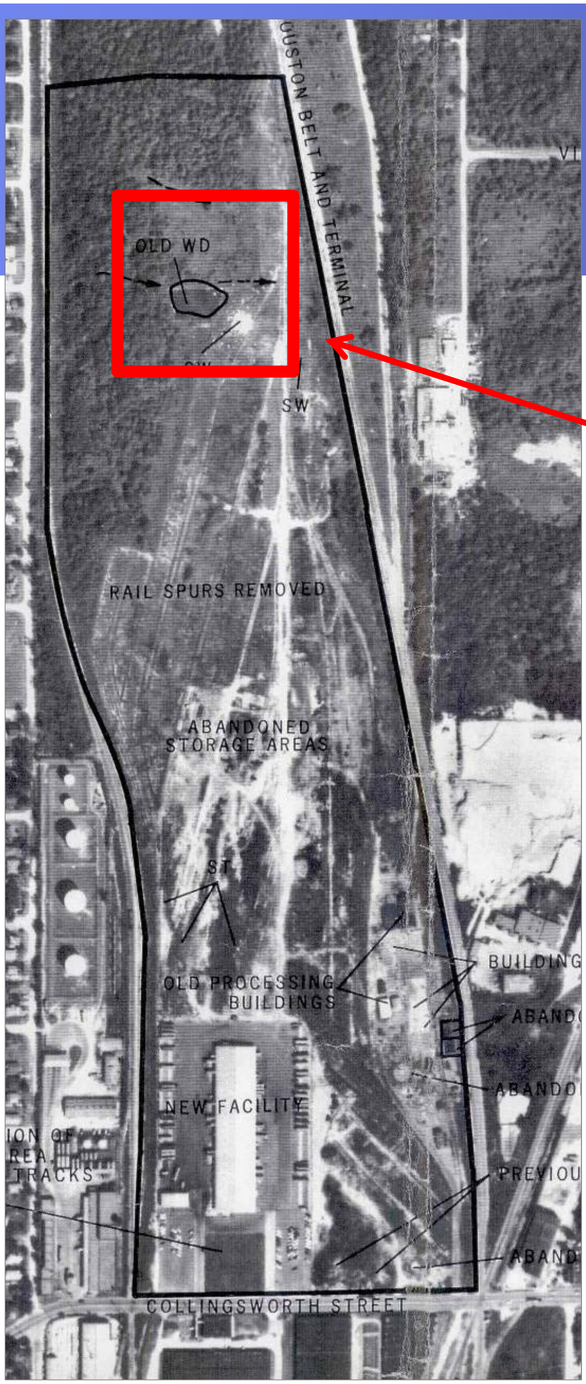
Central Area used for Wood Storage

Coal Tar Processing Plant in Southeast Area

Wood Treating Process Area

History

Aerial Photograph - 1964



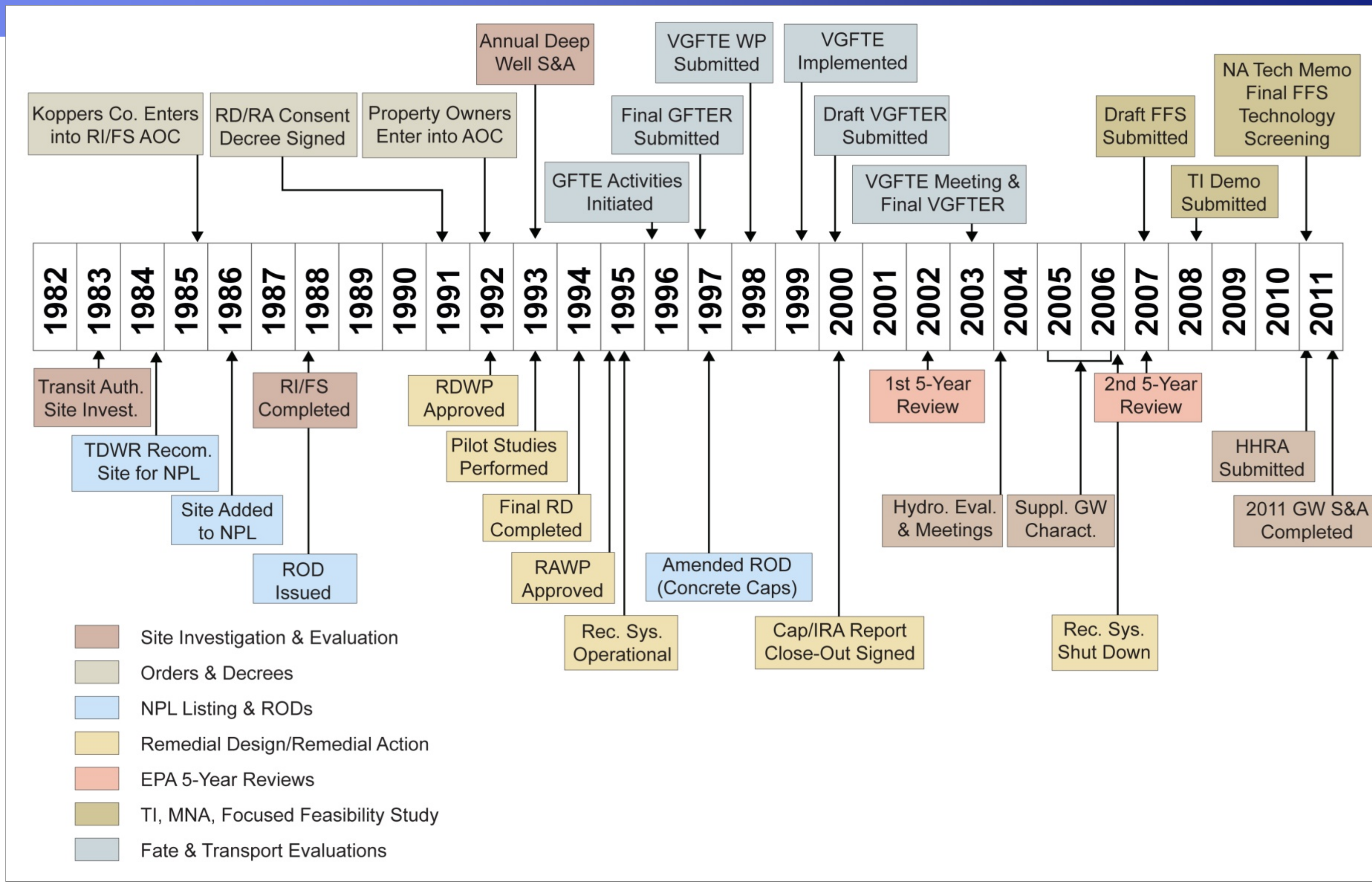
Pond

History

Aerial Photograph - 2011

History

Timeline



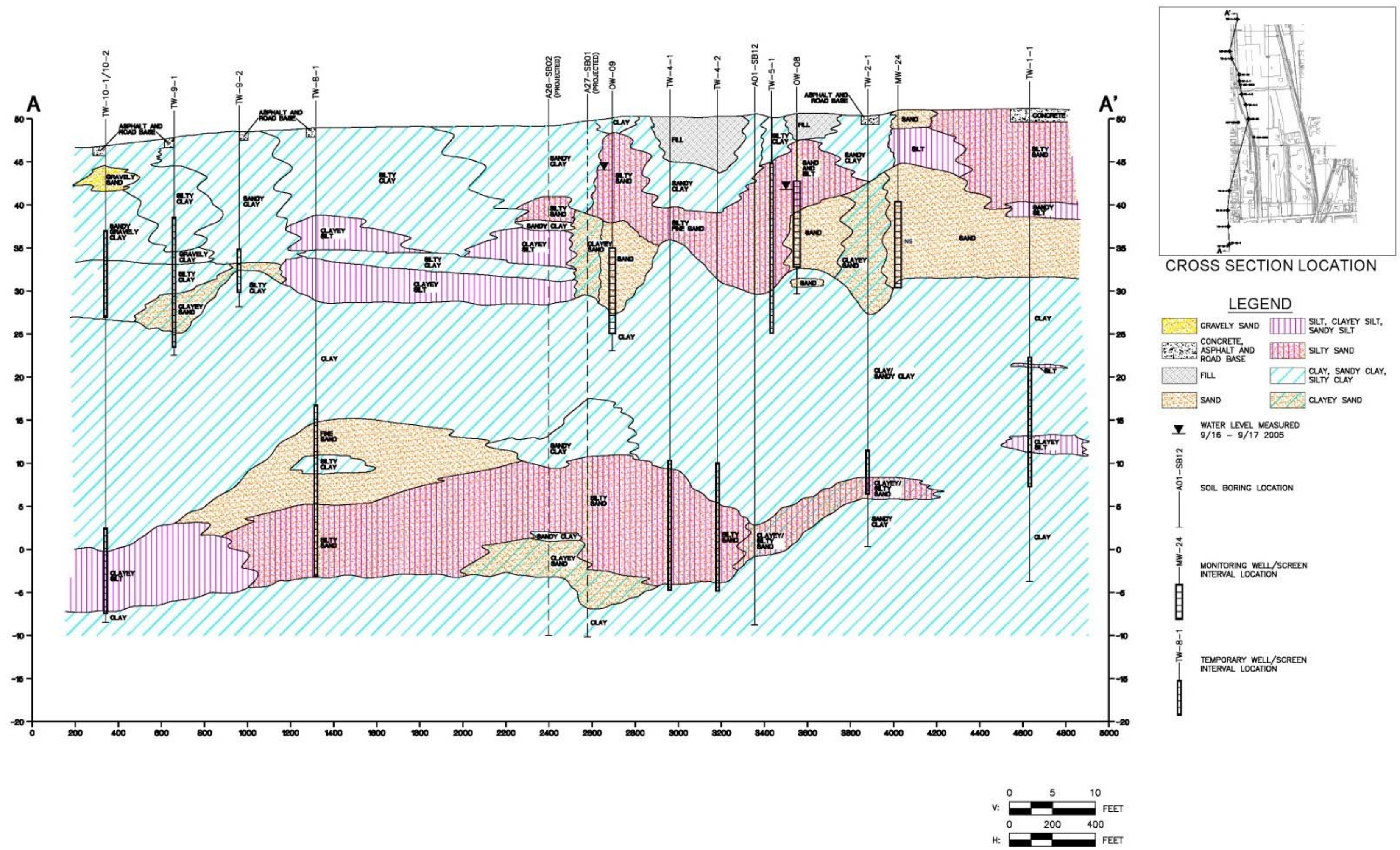
Conceptual Site Model
Site Characterization Efforts

- Remedial Investigation (1988)
- Groundwater Fate and Transport Evaluation (1997-98)
- Verification of Groundwater Fate and Transport Evaluation (1999-2000)
- Supplemental Groundwater Characterization (2005-06)

KEY ENVIRONMENTAL INCORPORATED
Beazer

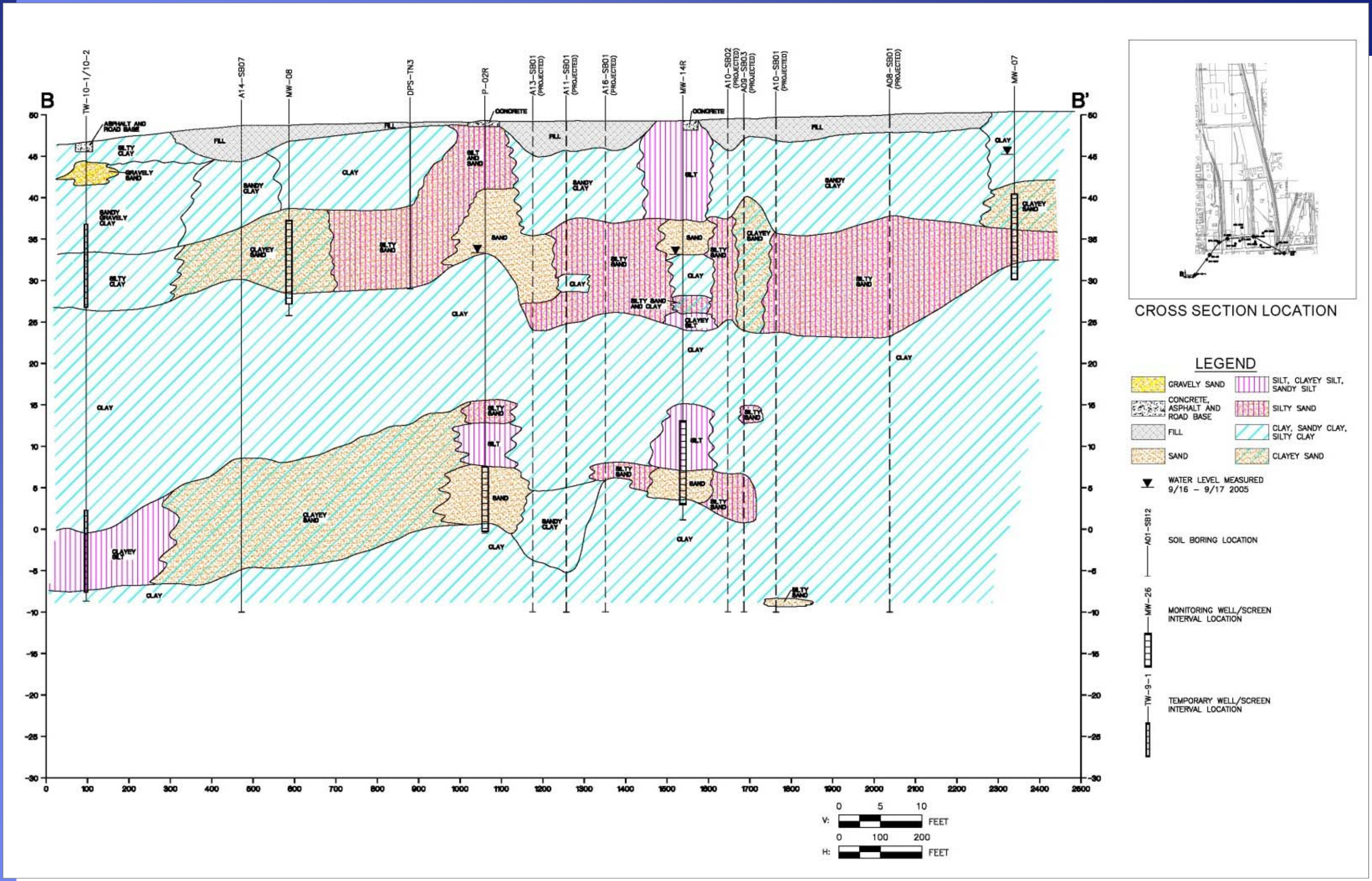
Conceptual Site Model

Geologic Cross-Section A-A’

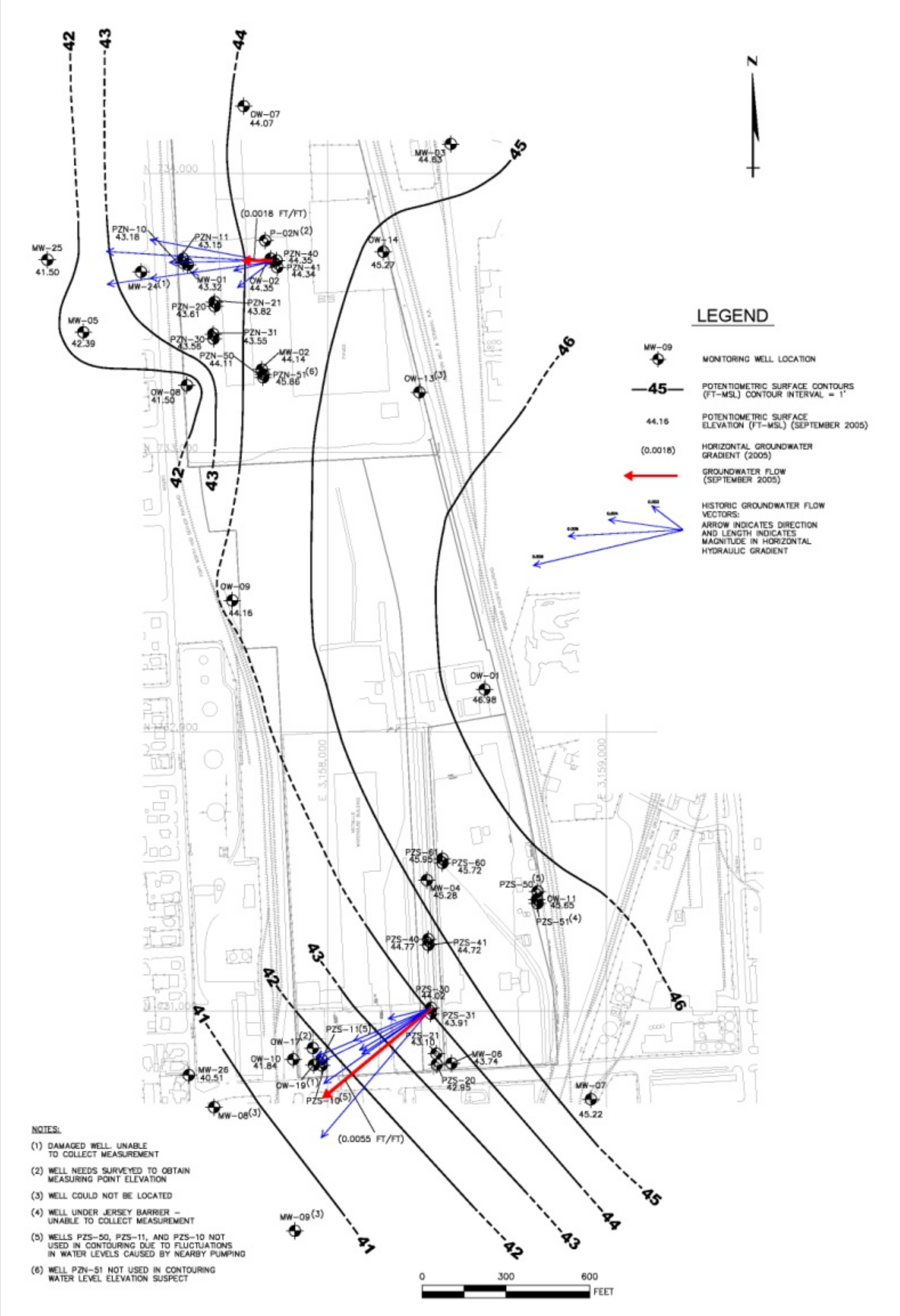


Conceptual Site Model

Geologic Cross-Section B-B'

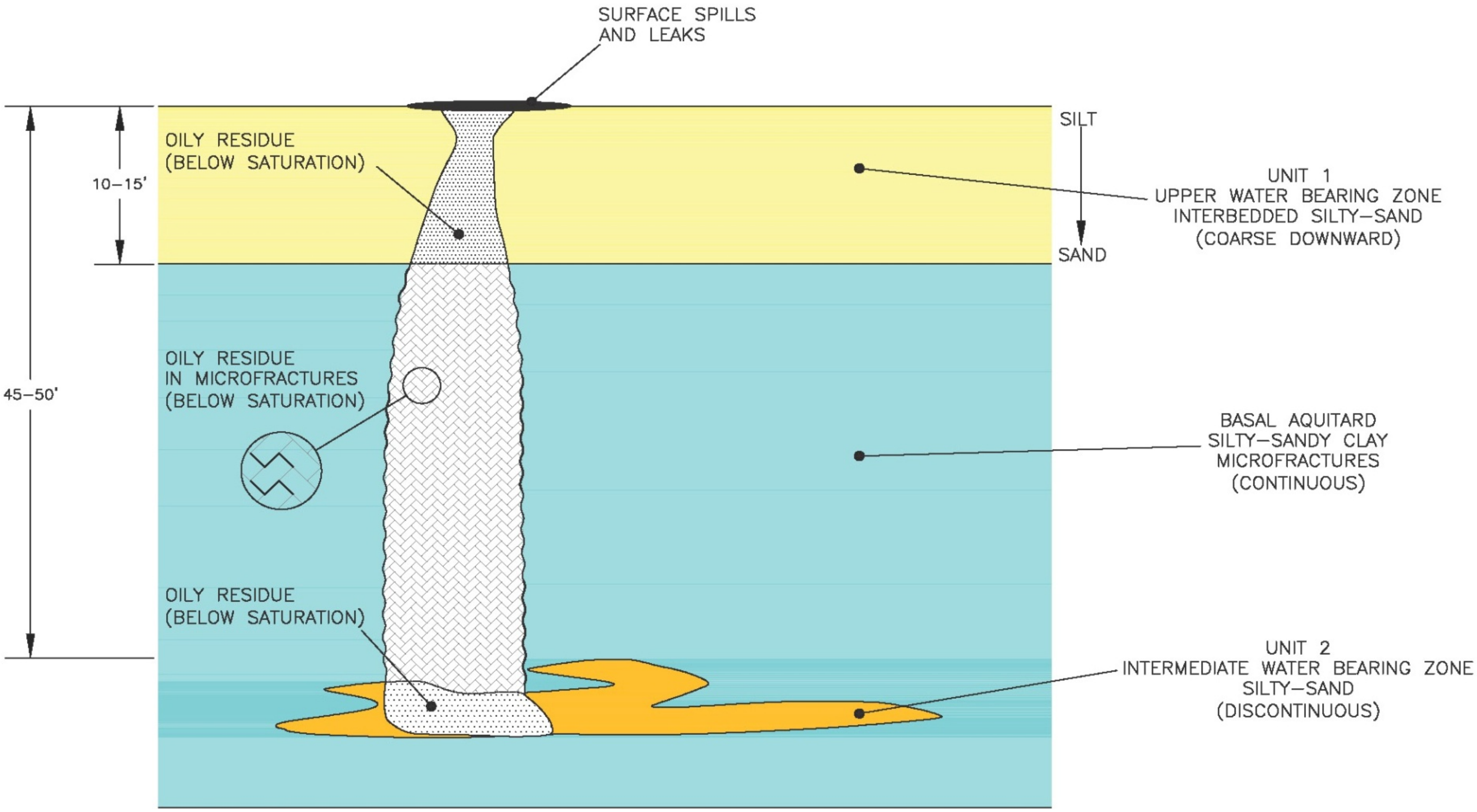


Conceptual Site Model
Potentiometric Surface Contour Map



Conceptual Site Model

Migration Mechanism



KEY ENVIRONMENTAL INCORPORATED
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Conceptual Site Model

Representative Boring Logs – South Area

LOG OF SOIL BORING
REMEDIAL INVESTIGATION
SOUTH CAVALCADE SITE
HOUSTON, TEXAS

FIGURE NO.

BORING NO.: SCK-A13-SB01
PROJECT NO.: 85-317
CLIENT: Koppers Company, Inc.
LOCATION: N 730,860 E 3,158,060
GROUND ELEVATION: 49.4'

SURROGATE ANALYSES — METALS, PPM; HEADSPACE READING, PPM

DEPTH, FT.	SAMPLES	SAMPLE DEPTH	SPLIT (S) DUPLICATE (D)	SOIL CLASSIFICATION	ARSENIC (As)	CHROMIUM (Cr)	COPPER (Cu)	LEAD (Pb)	ZINC (Zn)	TOTAL AROMATIC HYDROCARBONS, PPM	LAB	FIELD
	01T	1.5		Tan and light gray SANDY CLAY (CL) "FILL" w/roots, shells -w/solidified tars, creosote odor @ 2' -w/oily residue @ 3'							0	0
	02T	3.5			BDL	BDL	BDL	BDL	4749	13000	7	8
5	03T	5		Dark gray CLAYEY SAND (SC) "FILL" w/gravel, roots, wood, oily residue, creosote odor							23	46
	04T	7.5		Tan and light gray SANDY CLAY (CL) w/sand filled vertical fissures, oily residue, creosote odor							17	23
	05T	9.5									10	19
10												
	06T	12									24	35
	07T	13									11	32
15	08T	15.5		Tan SAND (SP) w/oily residue, creosote odor	BDL	BDL	BDL	BDL	2692	8500	36	37
	09S	17.5									54	25
20				-w/clay layers below 21'								
	10T	23		Light gray and light reddish brown SILTY SAND (SM) w/oily residue, creosote odor	128	187	30	229	78	658	5	19
25				Light gray and reddish brown CLAY (CH) w/slickensides, oily residue, creosote odor								
	11T	28		-w/silt partings @ 26' -w/silt partings @ 28'							7	19
30	12T	30		-slightly sandy @ 30'							5	30
	13T	32									7	27
	14T	33.5									3	10

SAMPLE IDENTIFICATION
T – 3 in. THIN-WALLED TUBE
S – 2 in. SPLIT-BARREL
A – AUGER

WATER LEVEL DATA

DATE	TIME	WATER DEPTH, FT	CAVED DEPTH, FT

DATE STARTED: 4-7-86
DATE COMPLETED: 4-7-86
DATE GROUTED: 4-7-86
DRILLER: Van and Sons
TECHNICIAN: Wayne D. Turney

LOG OF SOIL BORING
REMEDIAL INVESTIGATION
SOUTH CAVALCADE SITE
HOUSTON, TEXAS

FIGURE NO.

BORING NO.: SCK-A13-SB02
PROJECT NO.: 85-317
CLIENT: Koppers Company, Inc.
LOCATION: N 730,780 E 3,158,110
GROUND ELEVATION: 48.5'

SURROGATE ANALYSES — METALS, PPM; HEADSPACE READING, PPM

DEPTH, FT.	SAMPLES	SAMPLE DEPTH	SPLIT (S) DUPLICATE (D)	SOIL CLASSIFICATION	ARSENIC (As)	CHROMIUM (Cr)	COPPER (Cu)	LEAD (Pb)	ZINC (Zn)	TOTAL AROMATIC HYDROCARBONS, PPM	LAB	FIELD
	14T	36		Light gray & reddish brown CLAY (CH) -w/slickensides, creosote odor @ 35' -slightly sandy w/calcareous nodules, creosote odor @ 36' -w/calcareous and ferrous nodules, oily residue, creosote odor @ 38'							9	8
	15T	38									21	12
	16T	39			BDL	BDL	BDL	BDL	BDL	117	17	12
40												
	17T	42									2	0
	18T	42.5									1	1
45	19T	46		Reddish brown & light gray SANDY CLAY (CL) -w/sand seams, creosote odor @ 44' -w/oily residue, creosote odor @ 48'							1	2
50	20T	50			105	BDL	29	BDL	BDL	59	7	7
	21T	52		Light gray & reddish brown CLAY (CH) -w/vertical sand seams @ 50'	BDL	BDL	BDL	BDL	BDL	BDL	2	1
	22T	53.5		-w/slickensides @ 54'							7	0
55	23T	55.5			BDL	BDL	32	BDL	BDL	BDL	6	0
				Bottom @ 56'								
60												
65												

SAMPLE IDENTIFICATION
T – 3 in. THIN-WALLED TUBE
S – 2 in. SPLIT-BARREL
A – AUGER

WATER LEVEL DATA

DATE	TIME	WATER DEPTH, FT	CAVED DEPTH, FT

DATE STARTED: 4-8-86
DATE COMPLETED: 4-8-86
DATE GROUTED: 4-8-86
DRILLER: Van and Sons
TECHNICIAN: Wayne D. Turney

Conceptual Site Model

Representative Boring Logs – South Area

LOG OF SOIL BORING

REMEDIAL INVESTIGATION
SOUTH CAVALCADE SITE
HOUSTON, TEXAS

FIGURE NO.

BORING NO.: SCK-A13-SB02
PROJECT NO.: 85-317
CLIENT: Koppers Company, Inc.
LOCATION: N 730,780 E 3,158,110
GROUND ELEVATION: 48.5'

Samples	Sample Depth	Split (S) Duplicate (D)	Soil Classification	Arsenic (As)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Total Aromatic Hydrocarbons, PPM	Headspace Lab	Headspace Field
01T	1.5		Dark gray SANDY CLAY (CL) "FILL" w/bricks, shells & roots							0	0
02T	4		Tan & gray SANDY CLAY (CL) w/bioturbation, oily residue, creosote odor -w/sand pockets @ 4'							0	0
03T	5.5		-w/ferrous nodules @ 6'	BDL	BDL	BDL	173	227	341	5	1
04T	7.5									4	3
05T	9.5									2	2
06T	12		Light gray SILTY SAND (SM) w/oily residue, creosote odor							4	8
07S	13.5			BDL	BDL	BDL	BDL	1285	17400	26	19
			Light gray & reddish brown CLAY (CH) w/oily residue, creosote odor								
08T	23		Light gray & reddish brown SILTY SAND (SM) w/oily residue, creosote odor	143	BDL	BDL	123	52	1890	49	44
09T	25.5									17	16
10T	28		Light gray & reddish brown CLAY (CH) w/silt partings, oily residue, creosote odor, slickensides							36	21
11T	30	D		BDL	122	BDL	BDL	BDL	BDL	9	6
12T	31.5		Light gray & reddish brown SILTY CLAY (CL) w/oily residue, creosote odor							14	17
13T	34		Light gray & reddish brown CLAY (CH) w/ferrous & calcareous nodules, slickensides, creosote odor							12	6

SURROGATE ANALYSES — METALS, PPM; HEADSPACE READING, PPM

SAMPLE IDENTIFICATION
T - 3 in. THIN-WALLED TUBE
S - 2 in. SPLIT-BARREL
A - AUGER

WATER LEVEL DATA: DATE | TIME | WATER DEPTH, FT | CAVED DEPTH, FT

DATE STARTED: 4-8-86
DATE COMPLETED: 4-8-86
DATE GROUTED: 4-8-86
DRILLER: Van and Sons
TECHNICIAN: Wayne D. Turney

LOG OF SOIL BORING

REMEDIAL INVESTIGATION
SOUTH CAVALCADE SITE
HOUSTON, TEXAS

FIGURE NO.

BORING NO.: SCK-A13-SB01
PROJECT NO.: 85-317
CLIENT: Koppers Company, Inc.
LOCATION: N 730,860 E 3,158,060
GROUND ELEVATION: 49.4'

Samples	Sample Depth	Split (S) Duplicate (D)	Soil Classification	Arsenic (As)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Total Aromatic Hydrocarbons, PPM	Headspace Lab	Headspace Field
15T	36		Light gray & reddish brown CLAY (CH) w/calcareous nodules, oily residue creosote odor							0	9
16T	37		Light gray & light reddish brown SANDY CLAY (CL) w/oily residue, creosote odor							12	17
17T	39.5		-w/ferrous nodules @ 39'							3	1
18T	41.5		Light gray CLAY (CH) w/creosote odor -slightly silty @ 41'							4	4
19T	46		Reddish brown & light gray SANDY CLAY (CL) w/oily residue, creosote odor	BDL	BDL	BDL	BDL	BDL	65	12	9
20T	47.5									12	4
21T	49.5		-w/sand pockets, @ 50'							10	4
22T	51.5			BDL	BDL	BDL	BDL	BDL	105	15	12
23T	53.5		Light gray & reddish brown CLAY (CH) -w/sand pockets, slickensides, calcareous nodules, creosote odor							3	6
24T	59.5		-reddish brown w/silt pockets and partings @ 58'	BDL	BDL	BDL	BDL	BDL	BDL	1	0
			Bottom @ 60'								

SURROGATE ANALYSES — METALS, PPM; HEADSPACE READING, PPM

SAMPLE IDENTIFICATION
T - 3 in. THIN-WALLED TUBE
S - 2 in. SPLIT-BARREL
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WATER LEVEL DATA: DATE | TIME | WATER DEPTH, FT | CAVED DEPTH, FT

DATE STARTED: 4-7-86
DATE COMPLETED: 4-7-86
DATE GROUTED: 4-7-86
DRILLER: Van and Sons
TECHNICIAN: Wayne D. Turney

Conceptual Site Model

Summary of DNAPL Observations

TABLE 2-1

DNAPL THICKNESS MEASUREMENT SUMMARY
TECHNICAL IMPRACTICABILITY DEMONSTRATION
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Well	DNAPL Thickness (ft)			Date of Most Recent	Comments
	Minimum	Maximum	Most Recent		
SHALLOW ZONE WELLS					
RWS-1	0	10.93	0.02	12/18/2006	
RWS-2	0	3.59	2	12/18/2006	
RWN-4	0	11	0	8/30/2006	
RWS-5	0	2.73	0.05	11/29/2006	
PZS-10	0	6.67	0	10/17/2006	
PZS-20	0.083	13	3.96	10/17/2006	
PZN-40	0	-	0	10/17/2006	DNAPL noted during historical groundwater sampling
PZN-41	0	-	0	10/17/2006	DNAPL noted during historical groundwater sampling
PZS-50	0.08	0.62	0.26	10/17/2006	
PZS-51	0	0.25	0	10/17/2006	
OW-02	0	2.42	0.07	10/17/2006	
OW-10	0	-	0	10/17/2006	DNAPL noted during historical groundwater sampling
OW-11	0.683	0.98	0.1	10/17/2006	
P-02N	-	0.8	0.8	9/17/2005	One available measurement
MW-06	0	3	0	9/17/2005	
INTERMEDIATE ZONE WELLS					
OW-20	-	1.27	1.27	9/16/2005	One available measurement
MW-12R	-	2	2	9/17/2005	One available measurement
ITW-02	-	2.4	2.4	9/17/2005	One available measurement

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Conceptual Site Model
GFTE Technical Approach

- Developed a Site Conceptual Model
- Conducted analytical modeling to evaluate fate and transport in shallow groundwater in Northern and Southern areas.
  - Selected source areas with greatest potential for migration to location of hypothetical future exposure
  - Used “Protective assumptions to ensure that the potential for future exposure to groundwater constituents is not underestimated.”
  - Evaluated transport with and without biodegradation
- Compared model simulation results with available groundwater analytical data

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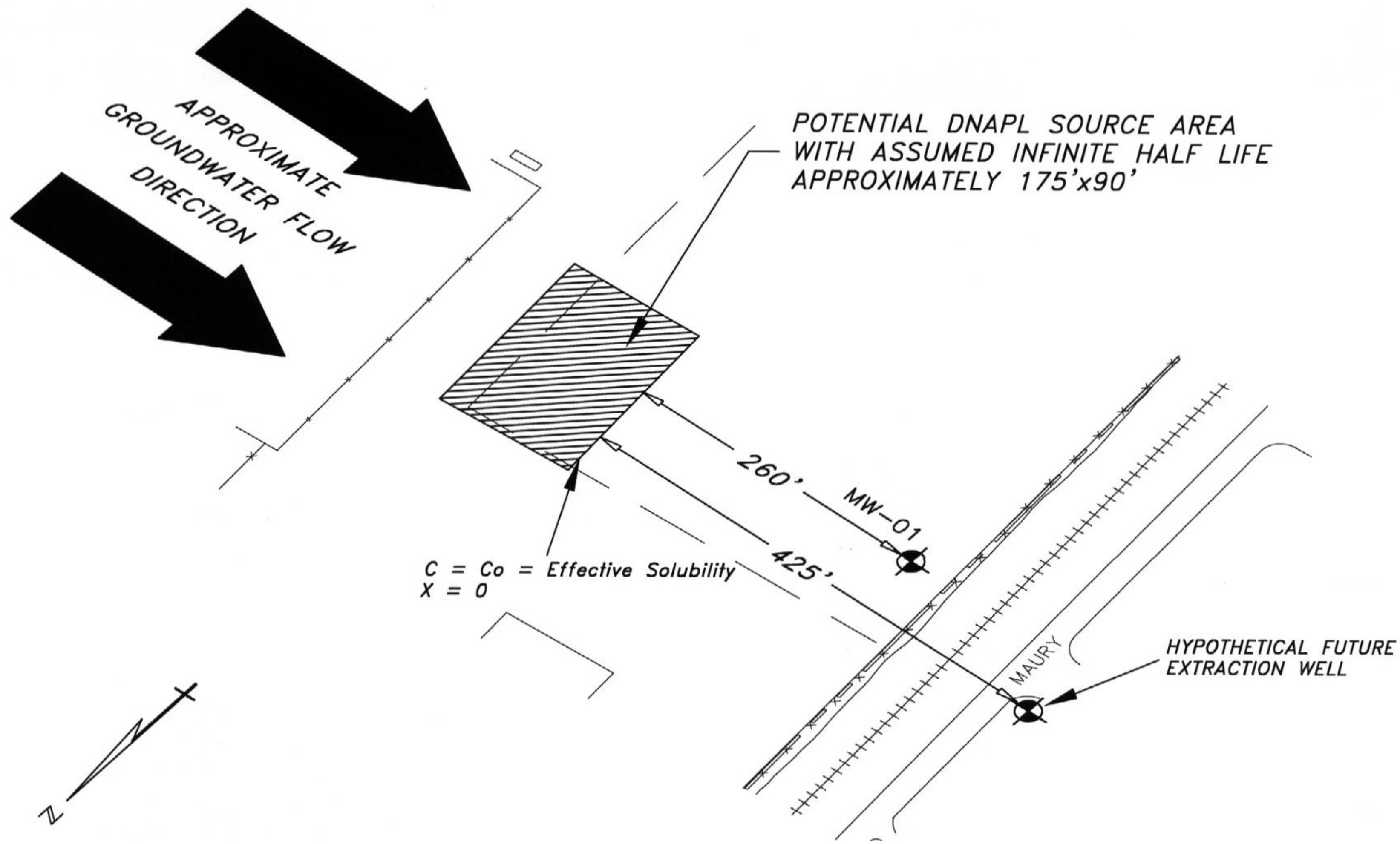
Conceptual Site Model

Conceptualization of Northern Area



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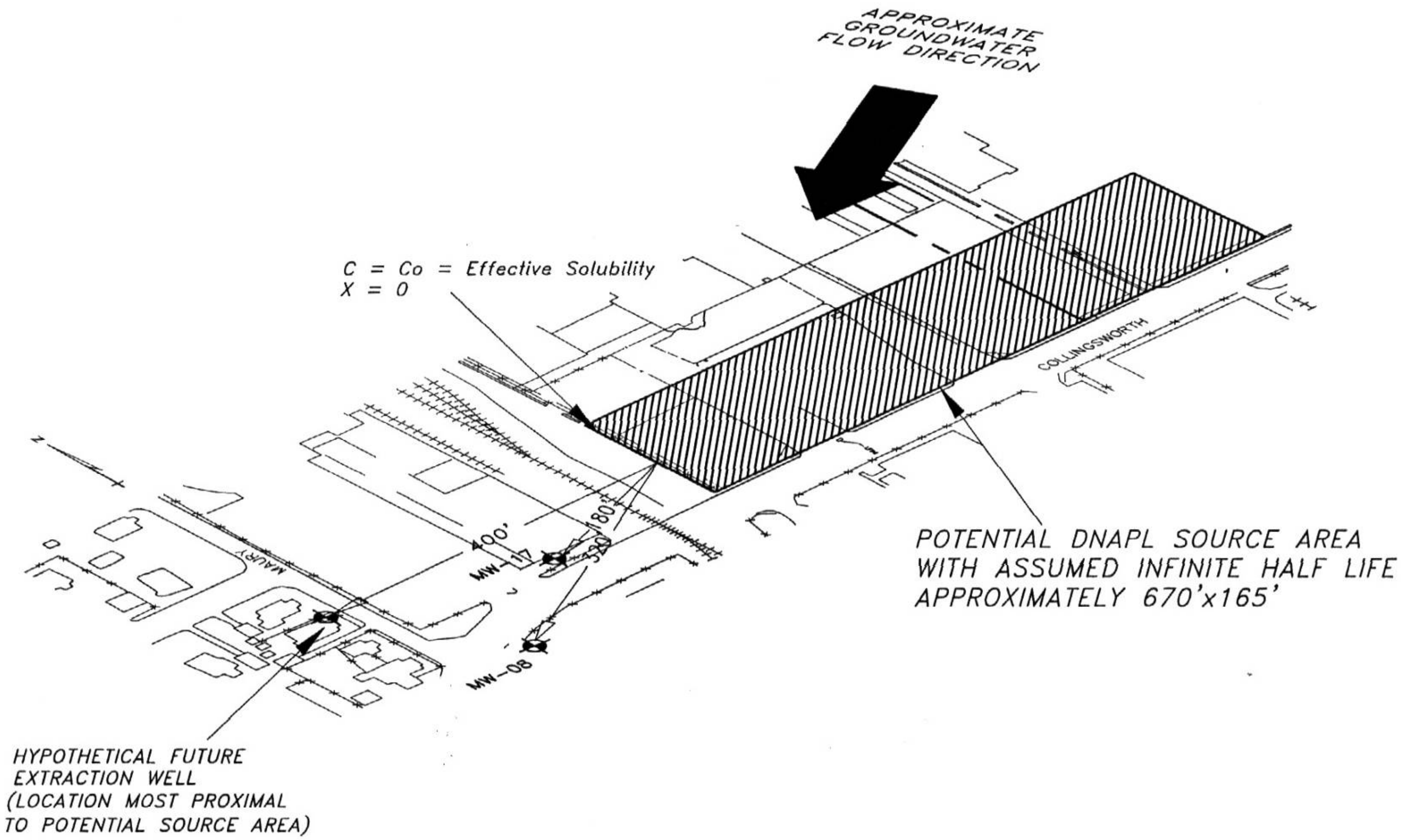
Conceptual Site Model

Conceptualization of Southern Area



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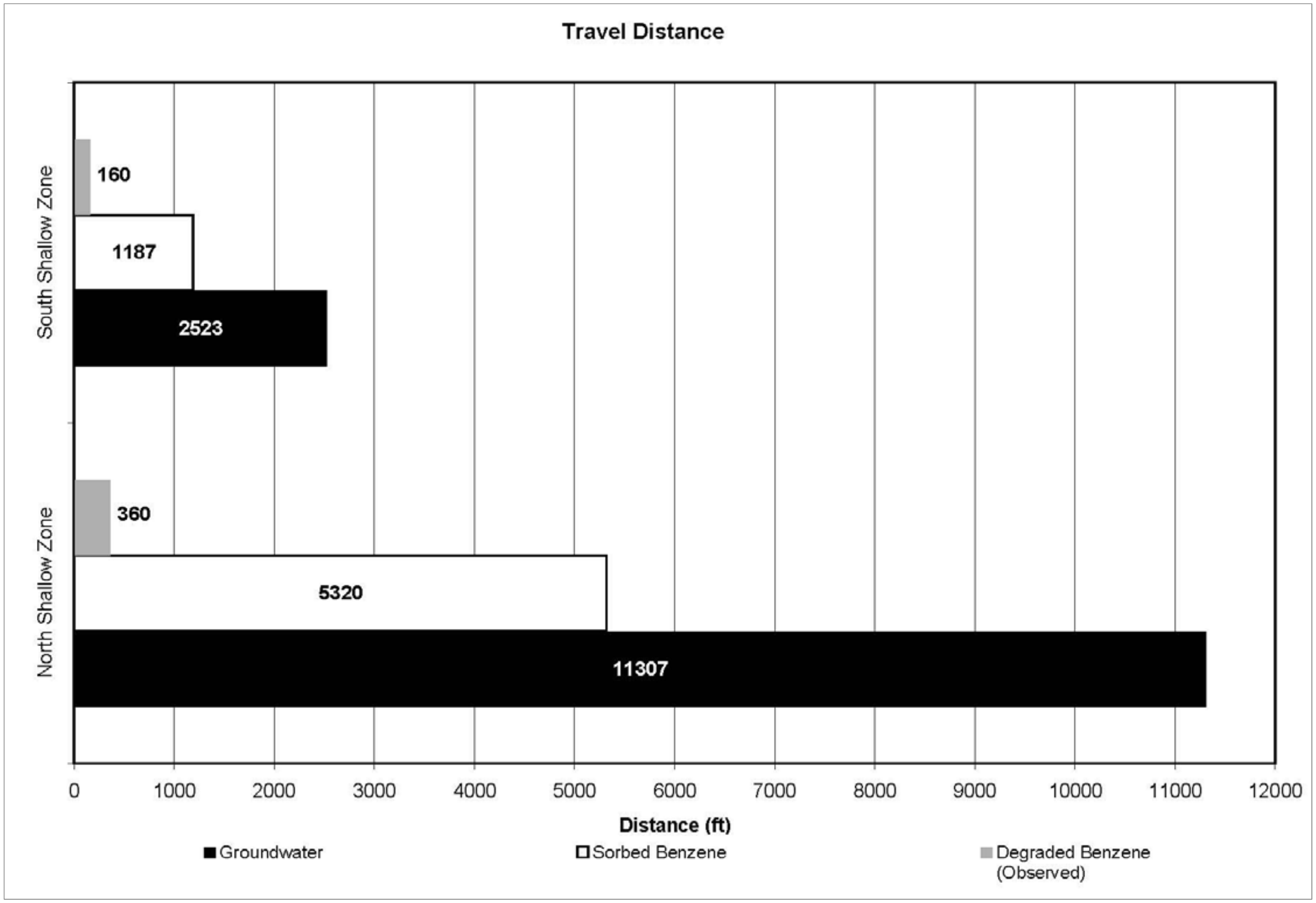
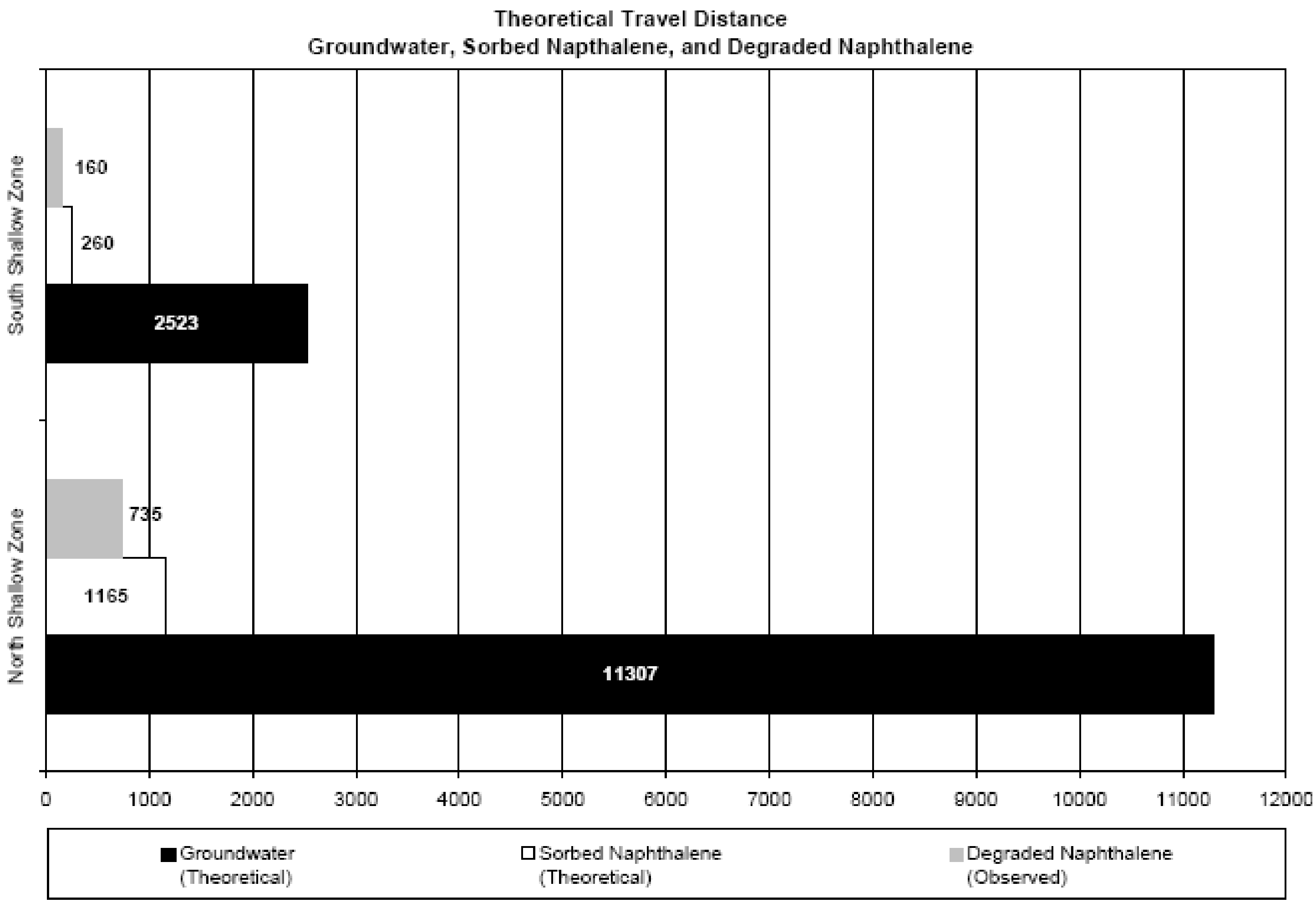
Conceptual Site Model

Observed vs. Non-Attenuated Travel Distances



Conceptual Site Model

Observed vs. Non-Attenuated Travel Distances



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Conceptual Site Model

GFTER Conclusions/Recommendations

- GFTER Concluded that a Monitored Natural Attenuation Remedy is Feasible on the Basis of the Following:
  - Constituent Transport and Concentrations Were Less Than Expected if Biodegradation Were Absent
  - Half-Life Analysis Indicated That Plumes are Stable
- GFTER Recommendations consisted of Additional Data Collection and Information Gathering Activities to Verify Findings

Conceptual Site Model

Verification of Groundwater Fate and Transport Evaluation Report (VGFTER)

- Work Plan Reviewed and Approved by EPA
- Field Activities Implemented in Nov./Dec. 1999
- Supplemental Work Completed in April and June 2000
- Report Submitted in July 2000

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Conceptual Site Model

VGFTER Scope

- Delineation of Plume Cores
- Evaluation of COI Concentrations in the Plumes
- Confirmation of Groundwater Flow Direction and Gradients
- Evaluation of Natural Attenuation Indicators
- Evaluation of Natural Attenuation By-Products
- Evaluation of Groundwater Usage
- Determination of DNAPL Properties
- Measurement or Organic Carbon Content in Aquifer Matrix

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Conceptual Site Model
VGFTE Results

- GFTE Model Input Parameter Values are Adequately Representative of Site Conditions
- Well Locations Used for GFTE Modeling Represent Conditions Within the Plume Core
- COI Concentrations at Downgradient Locations Agree with GFTE Predictions
- No Other Significant Dissolved Plumes Exist Outside the Identified Source Areas
- Data Indicate that Natural Attenuation is Occurring
- MNA Remedy is Appropriate

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Conceptual Site Model

Supplemental Groundwater Characterization: Objectives

- To evaluate potential preferential groundwater migration pathways for the shallow and intermediate aquifers;
- To refine the delineation of the dissolved phase plume in the area southwest of the Site; and,
- To provide additional data and information to support the design of an MNA monitoring network.

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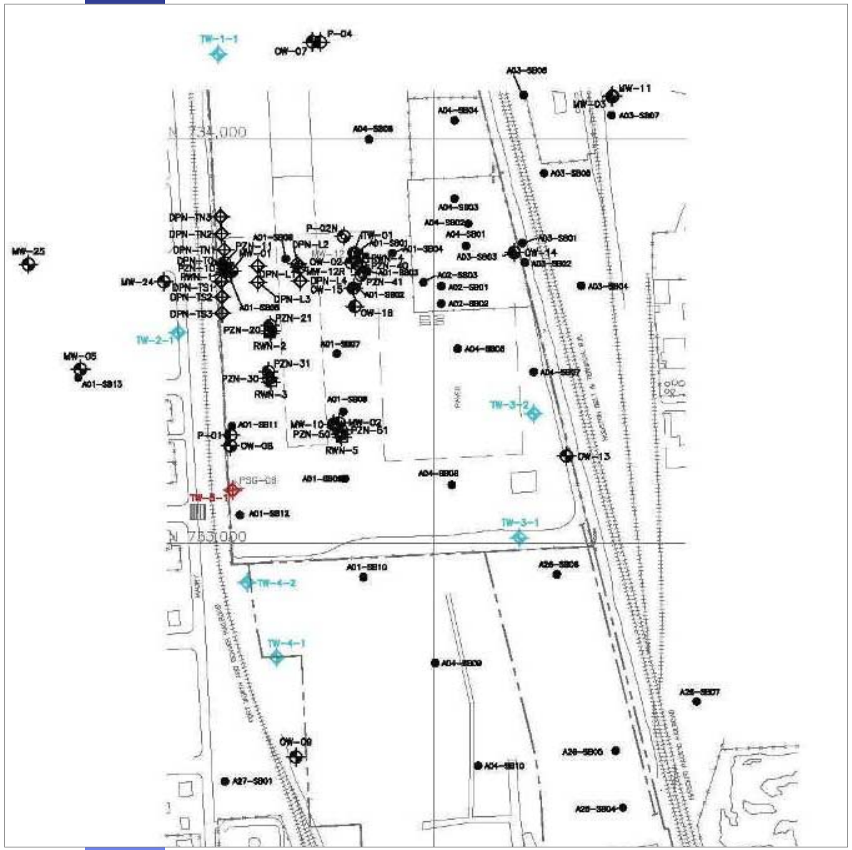
Conceptual Site Model

Temporary Well Location Map



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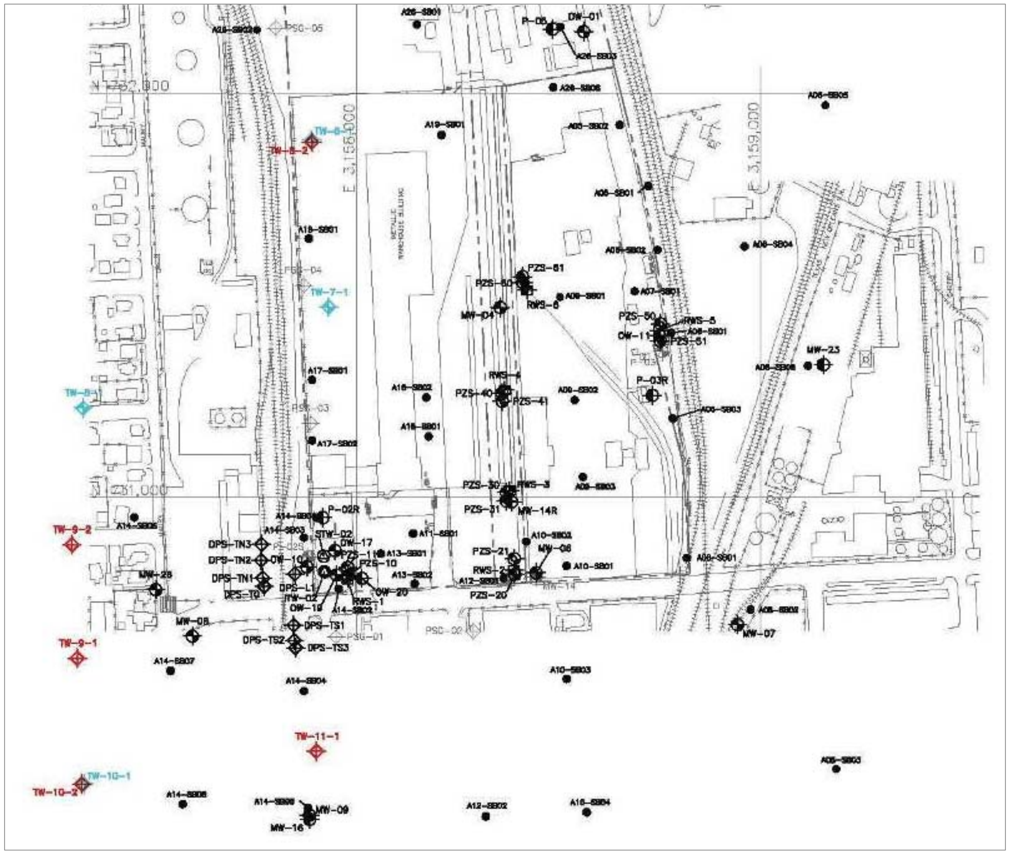

South

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Conceptual Site Model

Supplemental Groundwater Characterization: Results

- Potential preferential pathways were ruled out
- Dissolved plume southwest of the Site is defined and is limited in extent
- Data will aid the development of an appropriate MNA program

Note: As a result of this study (and others) EPA and TCEQ requested that Beazer prepare a Focused Feasibility Study to support a request to change the groundwater remedy.

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Conceptual Site Model

Exposure Considerations

- Industrial/Commercial Land Use – Source Areas capped with concrete
- Groundwater Use On-Site is Prohibited
- No Groundwater Use Currently Exists Off-Site
- Planned Highway Will Further Isolate the Site
- Future Use of Groundwater is Highly Improbable Due to Low Yield, Poor Quality and Cost Factors
- HGCSD Production Well Permitting Process Provides a Means for Notification
- Vapor Intrusion to Indoor Air is not of Concern With Existing Structures

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Conceptual Site Model
Summary

- Fine-Grained Geologic Formations
- Yields Very Little Water & Virtually No DNAPL
- Site Hydrogeologic Conditions and Constituent Properties Favor Limited Migration
- Significant Natural Attenuation Occurring
- Active, Productive Trucking Terminal
- Institutional & Engineering Controls in Place
- No Exposures Under Existing Site Conditions
- Exposure Potential Extremely Remote Under Future Site Conditions

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DNAPL Recovery System

Remedial Design (1992 – 1994)

- Defined Areas of Potentially Recoverable DNAPL Based on Composite Evaluation of Several Criteria
  - Confining Unit Configuration
  - Location of Former Process Areas
  - Soil Analytical Data
  - Groundwater Analytical Data
  - DNAPL Measured in Monitoring Wells

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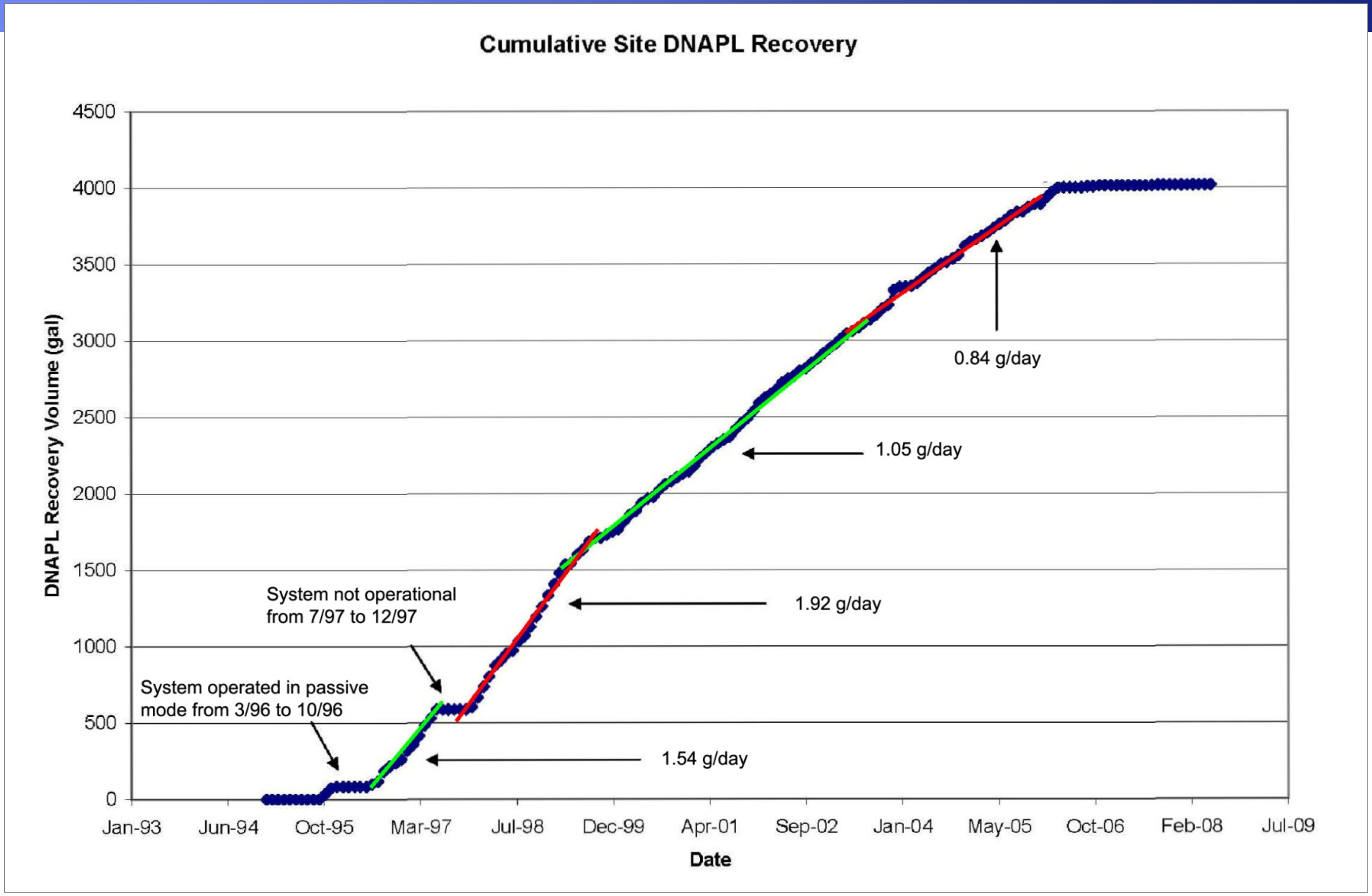
DNAPL Recovery System
DNAPL Removal



DNAPL Recovery System
SUMMARY

- Transmissivity of the Geologic Matrix is Low
- DNAPL Entered Formations over 50+ Years of Operation (1910-1962)
- DNAPL Recovery Wells Sited in Potential Productive Source Areas
- Limited DNAPL Recovered via Active Groundwater Pumping (<averaged ~360 gal/yr)
- DNAPL Recovery Rapidly Approached Diminishing Returns (<1 gal/day)
- Recent DNAPL Gauging Shows Minimal Accumulation (<4 gal accumulated across a total of 65 wells over 6 years)
- Weathering Has Reduced Mobility and Recoverability

Focused Feasibility Study
Alternative Evaluation

- Alternative 1 - No Further Action
- Alternative 2 - MNA With No Further Action for Source Zone
- Alternative 3 - MNA With Continued Source Removal
- Alternative 4 - In-Situ S/S of Accessible Source Materials

- Evaluated Per to the 9 CERCLA/SARA Criteria

- Recommended Alternative: Alternative 2

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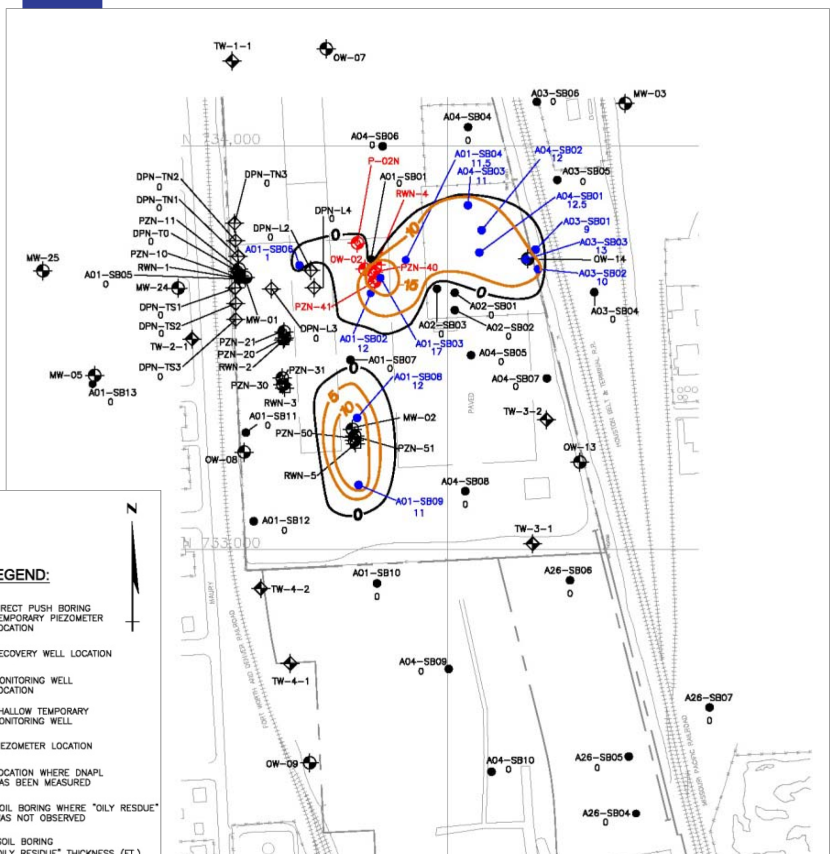
Focused Feasibility Study

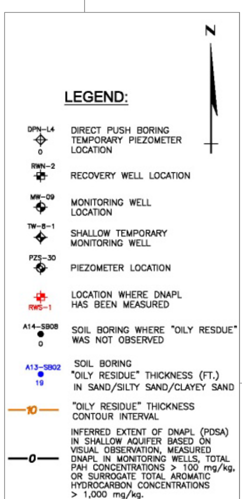
Temporal Considerations

- Time to Achieve ARARs a Major Consideration
- Source depletion time estimated based on representative DNAPL concentration of 1,000 mg DNAPL per kg of soil in source areas
- ~3.4 years to deplete soluble components from 1 cubic meter of soil
- Mininum of 170 years to deplete soluble components from source areas (min 50 m length)

Focused Feasibility Study

Source Extent in Shallow Zone





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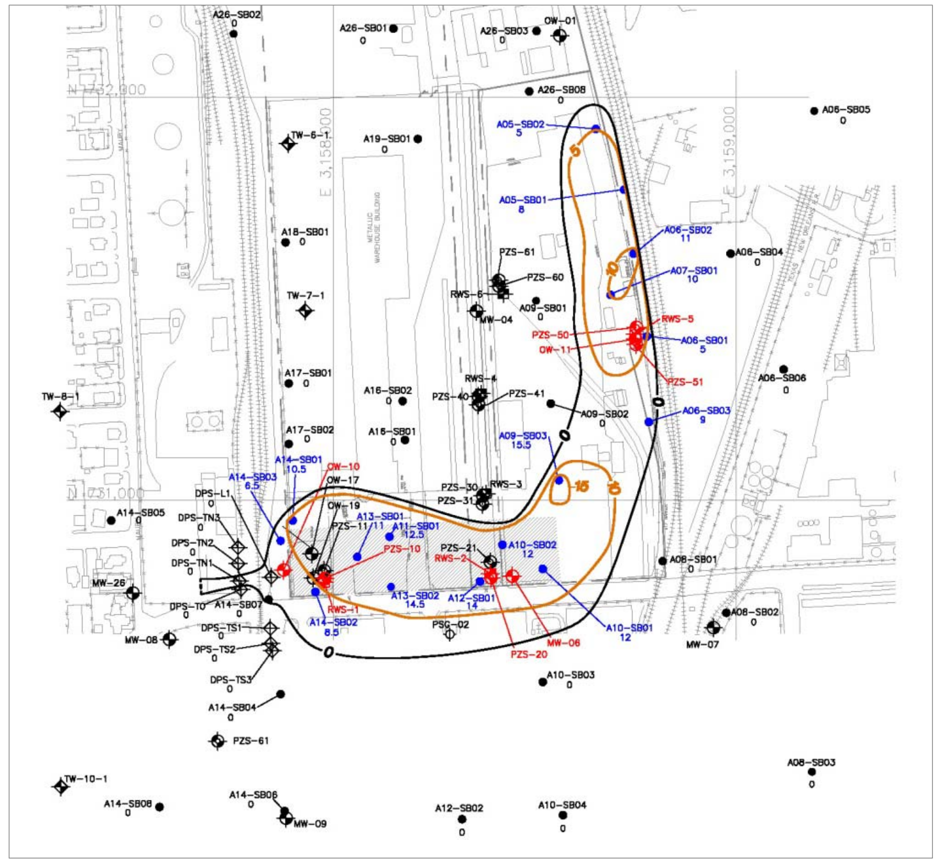

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Focused Feasibility Study
Source Volume Estimation

- Purpose was to gauge the effectiveness of active DNAPL recovery.
- Reviewed all logs to determine presence/ absence of source material and estimated thickness of affected soil.
- Constructed isopach maps of affected soil thickness to allow for soil volume estimation.
- Used estimated 1,000 ppm concentration to estimate mass of source material and DNAPL density to convert to a volume of liquid.
- Estimated total residual DNAPL volume of 242K gal (~4K gal removed to date)

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Focused Feasibility Study

Source Distribution

Geologic Unit	Soil Source Volume (m^3)	Estimated DNAPL Volume (m^3)	DNAPL to Soil Ratio
Shallow Zone	142,757	254	0.0018
Intermediate Aquitard	327,265	582	0.0018
Interbedded Zone	45,684	81	0.0018
Totals	515,706	917	0.0018

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Focused Feasibility Study

Source Distribution

Geologic Unit	Estimated DNAPL Volume (gal)	Percentage of Total
Shallow Zone	67,096	27.7%
Intermediate Aquitard	153,815	63.5%
Interbedded Zone	21,471	8.9%
Totals	242,382	

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Technical Impracticability Demonstration

EPA (Region VI) 2008 Technical Memorandum

- Purpose – Presentation of Technical Arguments in Support of NA
- Methodology
  - Response to MNA Requirements
  - Investigative Findings
  - Application of Nine NCP Criteria

Technical Impracticability Demonstration

EPA (Region VI) 2008 Technical Memorandum: Conclusions

- Timeframe is Reasonable Compared to Other More Active Methods
- Other Methods Would Disturb Current Property Uses and are Costly
- Boring Information Supports the Presumption that the Source is Immobile and Dissolved Plumes are Stable
- Residual Source would Remain Following any Increased Source Removal Effort
- TI Waiver should be Established for Areas Impacted by Source Materials

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Technical Impracticability Demonstration

Methodology

- Implemented Consistent with EPA Guidance
- Evaluation Criteria
  - Hydrogeology
  - Contaminant Characteristics
  - Remedial System Design and Operations
  - Land Use Considerations
  - Exposure Considerations

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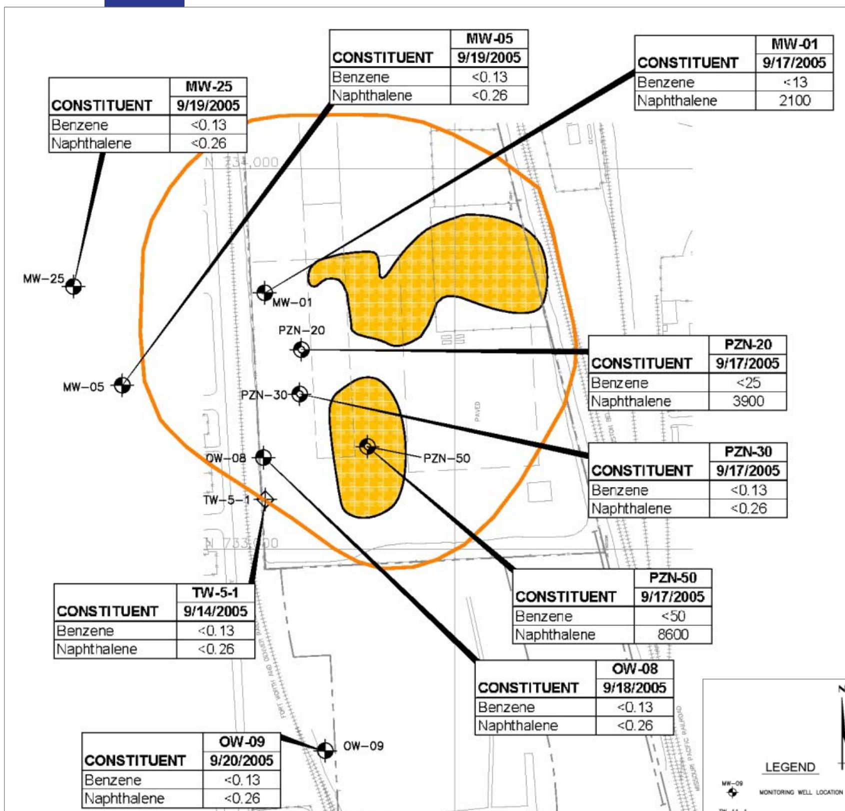
Technical Impracticability Demonstration

Conclusions and Recommendations

- All criteria favor the decision to establish a TI Waiver for Groundwater ARARs at the Site
- Implement MNA outside of the TI Zone
- Contingency Remedial Measures if necessary, if RAOs are not being met.

Technical Impracticability Demonstration

Proposed TI Zones - Shallow



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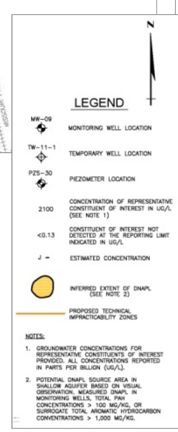

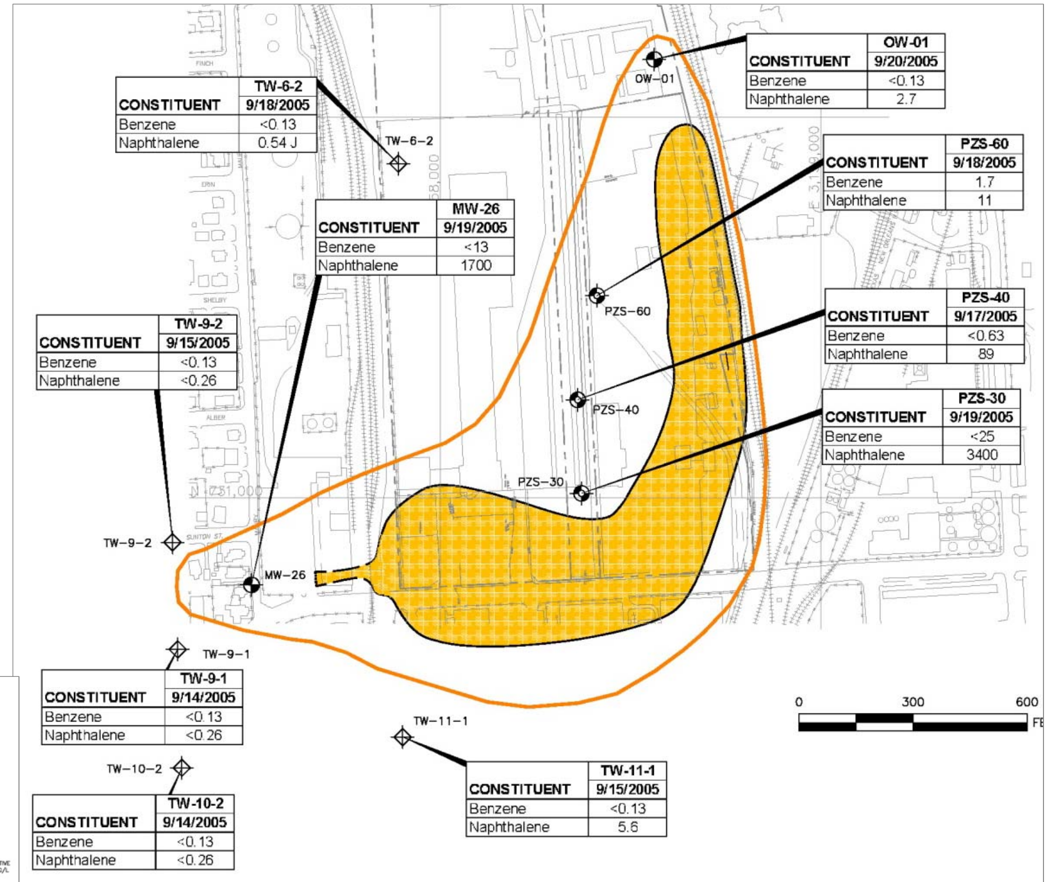

South

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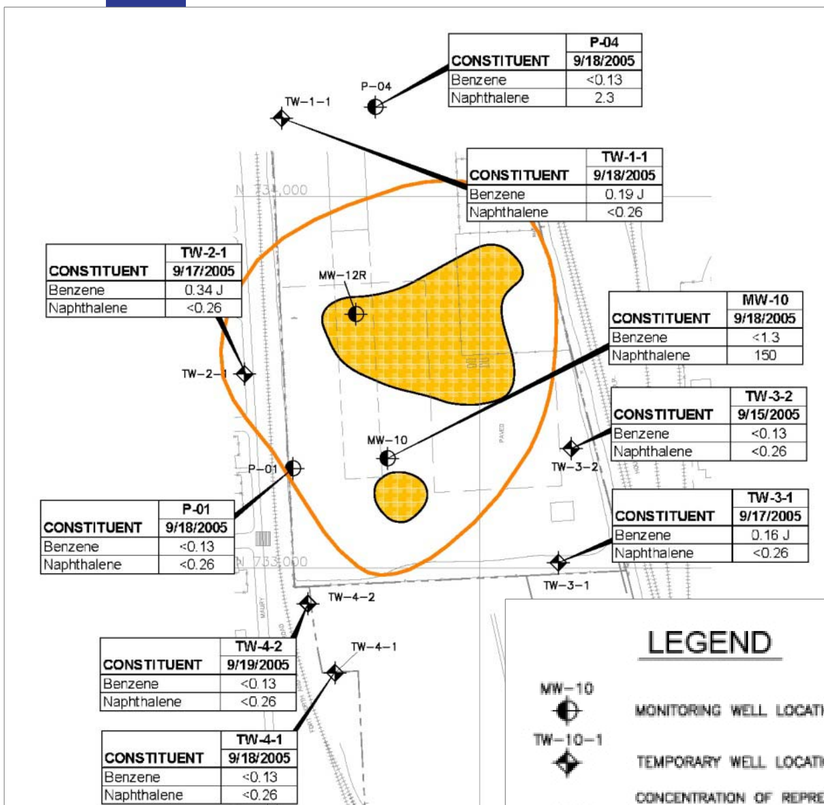
Technical Impracticability Demonstration

Proposed TI Zones - Intermediate



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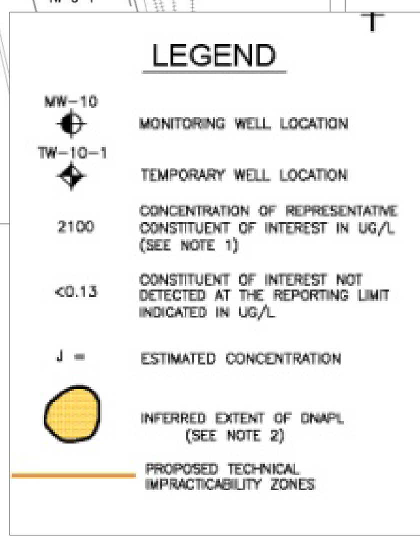

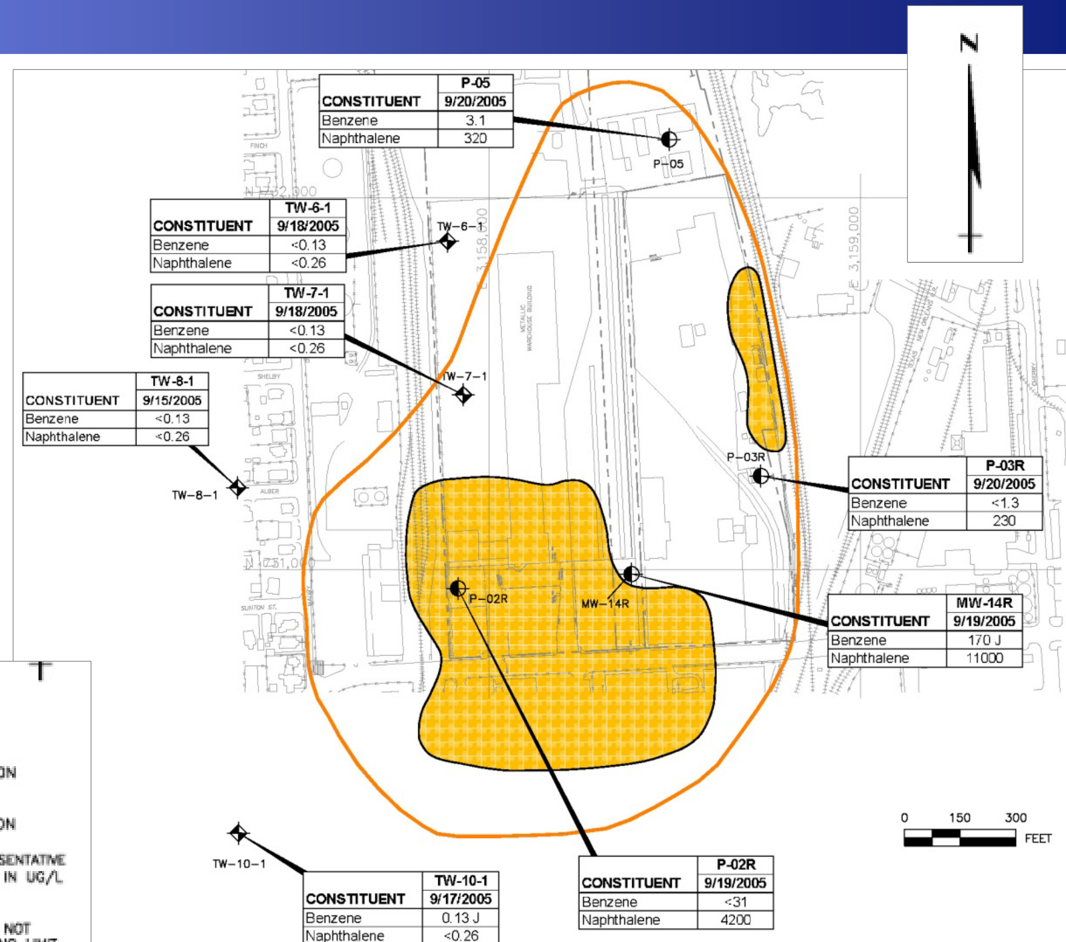

South

Evaluation of Monitored Natural Attenuation

2011 Beazer Technical Memorandum: Multiple Lines of Evidence

- Temporal Changes in COI (naphthalene and benzene) concentrations – Indicate stable conditions
- Geochemical Data for NA Indicators (SO4, Fe, Mn) – Demonstrate microbiological activity
- Fate and Transport Modeling - Biodegradation has limited the downgradient extent of COIs
- Assimilative Capacity Estimates – Sufficient to maintain stability of the dissolved phase plumes
- Active Microbiological Populations – Evidence of elevated level of bioactivity in impacted portions of the aquifer

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Evaluation of Monitored Natural Attenuation

2011 Beazer Technical Memorandum: Conclusions and Recommendations

- Substantial Biological Degradation is Occurring
- Given Lack of Exposure Potential, NA is Protective and Feasible
- Prepare an Amendment to the ROD to incorporate MNA
- Implement an Appropriate Monitoring Program

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Screening of Additional Technologies

- Limited Options for DNAPL Remediation in Tight Formations
- Thermal Methods May be Effective (Results to Date are Questionable)
- Thermal Methods Require Significant Above-Ground Appurtenances
- Thermal Methods are Very Costly and Have Inherent Health Hazards
- Mass of Source Precludes Use of Oxidation Technologies
- Gradient-Enhanced Pumping Shown to be Ineffective
- Gradient-Enhanced Pumping Will Not Address Residual DNAPL
- No Exposure Potential Under Future Site Conditions
- Significant Natural Attenuation is Occurring

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Action Items and Schedule

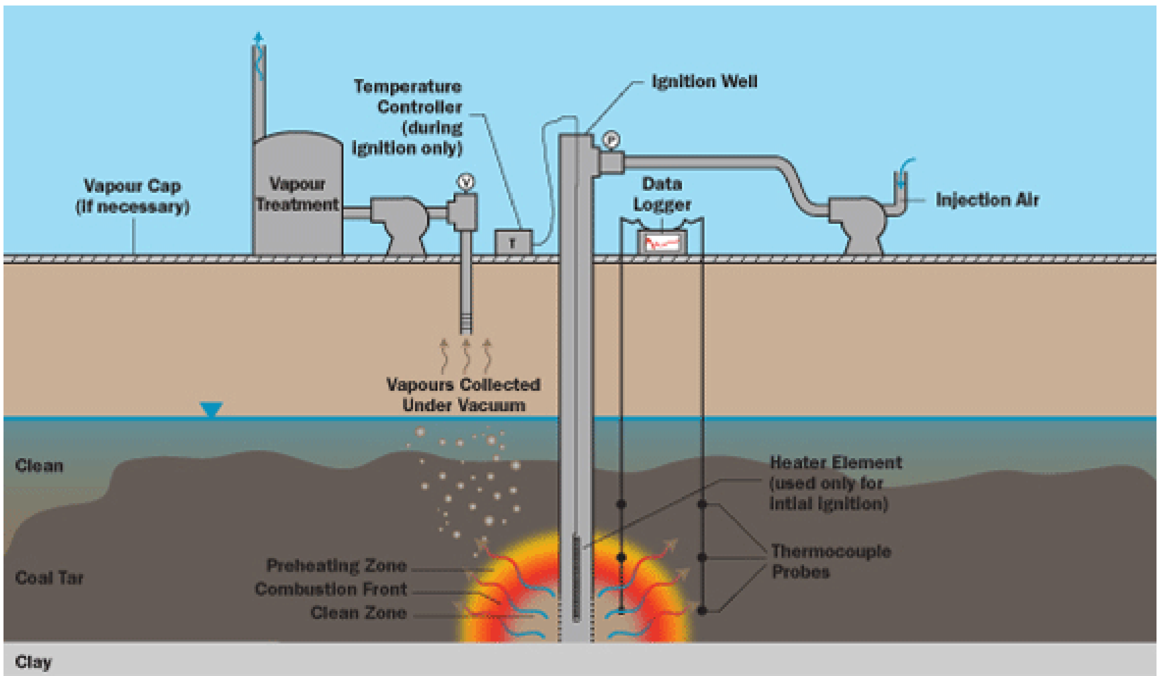
APPENDIX C

Preliminary Innovative Technology Review
Self-Sustaining Treatment for Active Remediation
South Cavalcade Superfund Site

Technology Description

The Self-Sustaining Treatment for Active Remediation (STAR) process appears to have originated as a result of consideration of the implications of underground coal seam fires such as that in Centralia, Pennsylvania which has been smoldering since 1962. The STAR technology appears to be applicable for remediation of a variety of coal and petroleum-based non-aqueous phase liquids (NAPLs) and relies on three primary factors to achieve remediation:

- Supply of an ignition source to induce smoldering
- Supply of oxygen to feed the combustion process
- Collection/treatment of off-gases generated as a result of combustion



Graphical display of In-situ STAR Application – Source: <http://star.siremlab.com>

The smoldering process is self-sustaining and will reportedly propagate at a rate of approximately 0.1 cm/min. Once the source mass is depleted, the combustion process ceases. Consequently, long-term uncontrolled burning does not occur.

In general, STAR appears to be a promising technology under favorable conditions. It is reportedly applicable for a wide range of non-aqueous phase liquids under various saturation conditions (e.g., free phase and residual) and can be implemented under both saturated and unsaturated hydraulic conditions. Destruction efficiencies on the order of 99% have been achieved on a pilot scale.

Technology Limitations

Although the technology is promising, its applicability to a wide range of geologic conditions has not been demonstrated. Bench scale work has focused on the use of porous media (sand and gravel). Bench and pilot scale work has also relied on the use of extremely-impacted material with high BTU content. The following photograph shows the type of material for the one case study that could be identified via an internet technology search:

Representative Photographs – Former Cresol Manufacturing Site, NJ – Source: <http://star.siremlab.com>

As is shown in the preceding photographs, the pilot test was completed for a site with cresols present at fully saturated conditions and the media is porous enough to promote free-phase flow into an excavation. While high concentrations of PAHs have been identified at the South Cavalcade site, the DNAPL is essentially residual in nature and consequently will not act as a self-sustaining combustible source similar to that for the New Jersey cresol site. As previously mentioned, porous media with high concentrations have been studied in proof of concept demonstrations, bench-scale column tests, and in drum and bin tests in the laboratory. However, these tests have been conducted on impacted sand or oily gritting wastes as is indicated on the technology vendor's website (***http://star.siremlab.com)***.

The geologic media and non-aqueous phase saturation conditions are considered important with respect to technology limitations for a number of reasons, as follows:

Under saturated groundwater conditions, the mass of DNAPL and its associated BTU content may be insufficient to vaporize the pore water. Under such circumstances the heat will dissipate, the smolder will be quenched, and the reaction will not be self propagating. The technology would then be equivalent to resistive heating or other thermal technologies where a constant input of energy is necessary. Preliminary calculations indicate that a Total Organic Carbon content of at least 3% (30,000 mg/kg) is necessary for sustainability for a weathered DNAPL with an assumed in-situ BTU content of 8,000 BTU/lb (see Attachment A). For comparative purposes, the concentrations of the primary organic constituents of interest at the Site (i.e., PAHs) ranged as high as 8,567 mg/kg in soils within the top 6 feet of soil and to 5,020 mg/kg in soils at depths greater than six feet below ground surface, as is summarized in Table 1 of the Record of Decision dated September 1988. Given the low concentrations, relative to those necessary to sustain combustion, it is considered unlikely that combustion will be self-sustaining at the South Cavalcade Site.

One of the primary requirements for the application of this technology is that ambient air be pumped into the formation. While air injection can typically be accomplished relatively easily in porous media, air injection is more problematic in tight geologic formations such as the silts and clays present at the South Cavalcade Site. Note that the graphic on the Sirem website shows the process applied in porous media above (not within) a clay layer.

Although the technology allegedly results in almost complete mineralization of the constituents (i.e., combustion products are water and carbon dioxide), other constituents such as naphthalene have been measured in the off-gas. The graphic provided on the Sirem website depicts a vapor cap (if necessary). The implication is that uncontrolled release of vapors is a possibility and this is considered much more likely where heterogeneous soils (such as those at the South Cavalcade Site) exist.

Conclusion

The STAR technology is considered promising for appropriate geologic media (e.g., porous media such as sand and gravel) and for source areas with Total Organic Carbon concentrations (attributable to hydrocarbons with BTU content on the order of 8,000 BTU/lb). The technology has not been demonstrated for low residual DNAPL masses and has not been demonstrated to be effective for tight formations (clay and dense silt) such as those present at the South Cavalcade site. The source masses and the geology of the South Cavalcade Site are expected to be rate limiting from the standpoint of heat generation capacity in the saturated zone and as a result of the inability to introduce oxygen to sustain combustion. Recovery of off-gases would also likely be problematic from the formation even if it were possible to induce smoldering. This technology does not appear to be viable for the South Cavalcade Site.

ATTACHMENT A

THERMAL CALCULATIONS

Smoldering Calculation Under Saturated Conditions

Basis

1 cf of soil at propagation front containing DNAPL at varying degrees of saturation.

Assumptions

Volume of media	1	1	cf
Porosity of media	30%	0.3	cf

Premise

Heat liberated by smoldering DNAPL must be equal to or greater than the heat needed to raise the water and soil temperature from 10^{o}C to a mininum of 100^{o}C and subsequently vaporize the water:

$$M_d \text{ x } LH_d = (M_w \text{ x } C_{p,w} \text{ x } \Delta T) + (M_s \text{ x } C_{p,s} \text{ x } \Delta T) + (M_w \text{ x } \Delta H_{v,w})$$

Where:
- M_d = the mass of DNAPL (lb)
- LH_d = the latent heat of DNAPL (BTU/lb)
- M_w = mass of water (lb)
- $C_{p,w}$ = heat capacity of water (BTU/lb/^{o}R)
- ΔT = change in temperature (^{o}F)
- M_s = mass of soil (lbs)
- $C_{p,s}$ = heat capacity of soil (BTU/lb/^{o}R)
- $\Delta H_{v,w}$ = Heat of vaporization of water (BTU/lb)

Inputs

Density of water	62.4	lbs/cf
Specific gravity of soil	1.5	none
Density of soil	93.6	lbs/cf
Specific gravity of creosote	1.07	none
Density of creosote	66.8	lbs/cf
DNAPL BTU Content (LH_d)	8000	BTU/lb
Specific Heat of Water ($C_{p,w}$)	1	BTU/lb/^{o}R
Specific Heat of Soil ($C_{p,s}$)	0.2	BTU/lb/^{o}R
Water Heat of Vaporization ($\Delta H_{v,w}$)	970.4	BTU/lb

	^{o}C	^{o}F	^{o}R
Initial Temp (10^{o}C)	10	50	510
Final Temp (100^{o}C)	100	212	672

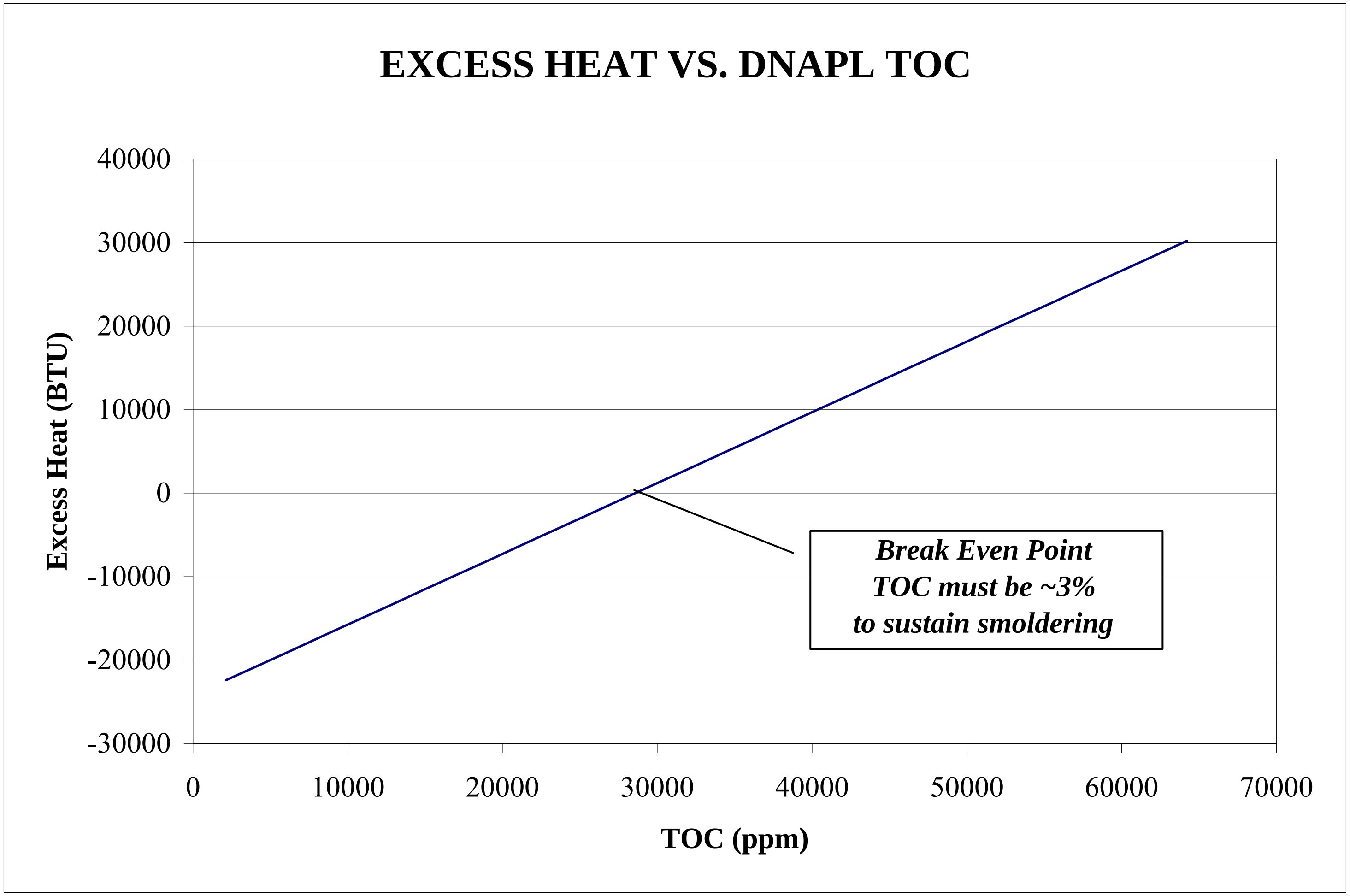
Calculations

Mass of soil (spec grav = 1.5)	93.6	lbs
Temperature Change	162	^{o}F

Ignore density and heat capacity changes as function of T.

006390

DNAPL Heat Calculations			Water Heat Calculations			Soil Heat Calculations		Estimated	Excess
Saturation Fraction	Mass (lbs)	$Heat_{out}$ (BTU)	Mass (lbs)	$Heat_{in,T}$ (BTU)	$Heat_{in,vap}$ (BTU)	Mass (lbs)	$Heat_{in,T}$ (BTU)	TOC (ppm)	Heat (BTU)
0.01	0.20	1602.432	18.5	3002.3	17984.2	93.6	3032.6	2140	-22416.8
0.02	0.40	3204.864	18.3	2972.0	17802.6	93.6	3032.6	4280	-20602.3
0.03	0.60	4807.296	18.2	2941.7	17620.9	93.6	3032.6	6420	-18787.9
0.04	0.80	6409.728	18.0	2911.3	17439.3	93.6	3032.6	8560	-16973.5
0.05	1.00	8012.16	17.8	2881.0	17257.6	93.6	3032.6	10700	-15159.1
0.06	1.20	9614.592	17.6	2850.7	17075.9	93.6	3032.6	12840	-13344.7
0.07	1.40	11217.024	17.4	2820.4	16894.3	93.6	3032.6	14980	-11530.2
0.08	1.60	12819.456	17.2	2790.0	16712.6	93.6	3032.6	17120	-9715.8
0.09	1.80	14421.888	17.0	2759.7	16531.0	93.6	3032.6	19260	-7901.4
0.10	2.00	16024.32	16.8	2729.4	16349.3	93.6	3032.6	21400	-6087.0
0.11	2.20	17626.752	16.7	2699.0	16167.6	93.6	3032.6	23540	-4272.6
0.12	2.40	19229.184	16.5	2668.7	15986.0	93.6	3032.6	25680	-2458.2
0.13	2.60	20831.616	16.3	2638.4	15804.3	93.6	3032.6	27820	-643.7
0.14	2.80	22434.048	16.1	2608.1	15622.7	93.6	3032.6	29960	1170.7
0.15	3.00	24036.48	15.9	2577.7	15441.0	93.6	3032.6	32100	2985.1
0.16	3.20	25638.912	15.7	2547.4	15259.3	93.6	3032.6	34240	4799.5
0.17	3.41	27241.344	15.5	2517.1	15077.7	93.6	3032.6	36380	6613.9
0.18	3.61	28843.776	15.4	2486.8	14896.0	93.6	3032.6	38520	8428.3
0.19	3.81	30446.208	15.2	2456.4	14714.4	93.6	3032.6	40660	10242.8
0.20	4.01	32048.64	15.0	2426.1	14532.7	93.6	3032.6	42800	12057.2
0.21	4.21	33651.072	14.8	2395.8	14351.1	93.6	3032.6	44940	13871.6
0.22	4.41	35253.504	14.6	2365.5	14169.4	93.6	3032.6	47080	15686.0
0.23	4.61	36855.936	14.4	2335.1	13987.7	93.6	3032.6	49220	17500.4
0.24	4.81	38458.368	14.2	2304.8	13806.1	93.6	3032.6	51360	19314.8
0.25	5.01	40060.8	14.0	2274.5	13624.4	93.6	3032.6	53500	21129.3
0.26	5.21	41663.232	13.9	2244.2	13442.8	93.6	3032.6	55640	22943.7
0.27	5.41	43265.664	13.7	2213.8	13261.1	93.6	3032.6	57780	24758.1
0.28	5.61	44868.096	13.5	2183.5	13079.4	93.6	3032.6	59920	26572.5
0.29	5.81	46470.528	13.3	2153.2	12897.8	93.6	3032.6	62060	28386.9
0.30	6.01	48072.96	13.1	2122.8	12716.1	93.6	3032.6	64200	30201.4


EXCESS HEAT VS. DNAPL TOC
Excess Heat (BTU)
40000
30000
20000
10000
0
-10000
-20000
-30000
0
10000
20000
30000
40000
50000
60000
70000
TOC (ppm)
Break Even Point
TOC must be ~3%
to sustain smoldering

APPENDIX D

Preliminary Technology Review
Surfactant-Enhanced Product Recovery
South Cavalcade Superfund Site

Technology Description

The Surfactant-Enhanced Product Recovery technology appears to rely on a borrowed traditional technology for treatment of NAPL and DNAPL impacted soils (surfactant flushing). A biodegradable surfactant amended with an oxidant is used to mobilize non-aqueous phase liquids which can then be recovered at the surface. The actual means by which this is accomplished is unclear based on the limited technical information provided by the vendor on their website <http://www.verutek.com/technologies/soil---groundwater-remediation/s-epr> which describes the technology as follows:

> ***"VeruTEK®'s Surfactant-enhanced product recovery (S-EPR™)*** *uses biodegradable plant based surfactants paired with a low level oxidant to lift contamination from the soil to the surface where it can either be treated or skimmed off and removed for future use. "*

The preceding statement is the extent of information available. Although a number of case studies are available on the website, virtually all of the case studies are for surfactant-enhanced in-situ chemical oxidation not S-EPR.

In general, there appears to be nothing particularly innovative about VeruTEK's methods for recovery of NAPLs/DNAPLs. It is suspected that their S-EPR technology is simply the use of enzyme surface active ingredients, hydrogen peroxide, and sodium carbonate (soda ash or washing soda). Formulations such as this have been used for cleaning applications for years (e.g., Oxydol, Proctor and Gamble's first laundry detergent, was introduced in 1927). The S-EPR technology is essentially a repackaged version of soil washing.

Technology Limitations

The removal of oil and grease using detergents is a proven technology for surfaces which are readily accessible (e.g., hard surfaces or clothes). However, for in-situ applications on the soil matrix, the use of surfactant-based recovery methods (aka in-situ soil washing) is primarily limited to the recovery of non-viscous materials such as chlorinated solvents. The technology has not been used effectively for viscous, coal-tar based DNAPLs. To the extent that washing technologies are effective for viscous, immiscible materials, difficulties are encountered with management of the washing fluid. Whereas volatile organic constituents can be stripped from the washing fluid (which allows for recycling and reuse of the washing fluid), semi-volatile constituents cannot be readily removed onsite, and, consequently, offsite disposal of the fluid may be necessary. Furthermore, the technology requires significant control to ensure that any mobilized materials are captured. The technology is potentially applicable for hydrogeologic settings consisting of porous (e.g., sand and gravel) and is not typically considered viable for fractured or low permeability media. The following observations regarding flushing versus hydrogeology were prepared by the Interstate Technology & Regulatory and Technology Council (ITRC) as summarized in a 2003 document entitled "Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing of DNAPL Source Zones". This document is available online at <http://www.itrcweb.org/Documents/DNAPLs-3.pdf>:

In considering the applicability of surfactant/cosolvent flushing, two key aspects of a site must be considered: the hydrogeologic setting and the characterization of the contaminant(s). Porous media sand and/or gravel settings are preferred to fractured rock, fractured clay, or low-permeability settings. This reflects the need to cycle fluids through a target zone in a reasonable period of time. The greater applicability of surfactant/cosolvent flushing in sands, silts, and gravels is supported by the generally poor results that have been achieved in silty clays and fractured rock. The hydrogeologic setting must be carefully taken into account during the design phase such that the application of surfactants or cosolvents into the subsurface does not create unwanted migration of contaminants.

In addition, it is important to note that a soil washing alternative was specified in the original Record of Decision (ROD) for the South Cavalcade Site. A pilot study was conducted in 1993 as part of the remedial design and it was determined that soil washing was ineffective. As a result, the ROD for the site was amended in 1997 to employ engineering controls (capping) rather than the soil washing technology. The following justification for the modification of the remedy is provided in the Amended ROD (EPA/AMD/R06-97/121, 1997):

In 1993, during the remedial design phase BEI conducted a soil washing pilot study; however, the study did not conclude that soil washing would provide overall protection of human health and the environment because forty percent of the soil volume could not be washed to meet the remedial goals. Consequently, there was no benefit to implement full scale operations.

Conclusion

The subsurface media at the South Cavalcade site consists of interbedded silts and clays, the specific media that the ITRC cites as media for which generally poor results are achieved. The primary difficulty with the application of this technology for the South Cavalcade site is limitations with respect to delivery of the surfactant and recovery of any potentially mobilized DNAPL (if any). Years of pumping operations have demonstrated the low permeability of the subsurface media at the site. The introduction of a surfactant (or a cosolvent) will have not effect on the intrinsic permeability of the matrix. In addition, costly onsite treatment or offsite disposal or surfactant wash water would be required as a result of the nature of the nonvolatile constituents present at the South Cavalcade site. As previously indicated, a pilot study has already demonstrated this that technology is ineffective. The potential risks of this technology with respect to mobilization of DNAPL are believed to far outweigh any potential benefits.

APPENDIX E

TABLE E-1A

COST ESTIMATE - REMEDIAL ALTERNATIVE 5
NOTH AREA IN-SITU CHEMICAL OXIDATION (ISBS) - SHALLOW ZONE ONLY
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Item	Description	Quantity	Unit	Cost
Direct Capital Costs				
1.01	Monitoring Well Replacement	3	$ 3,000	$ 9,000
1.02	Pilot Scale Study	1	$ 300,000	$ 300,000
1.03	Shallow Zone ISCO Drilling (LF)	10400	$ 25	$ 260,000
1.04	Shallow Zone ISCO Oxidant (CY)	56360	$ 50	$ 2,818,000
Total Direct Capital Costs				$ 3,387,000
Indirect Capital Costs				
2.01	Engineering and Design	5%		$ 169,350
2.02	Permitting and Fees	1%		$ 33,870
2.03	Construction Oversight (includes H&S)	75	$ 1,200	$ 90,000
Total Indirect Capital Costs				$ 293,220
Subtotal Capital Costs				
3.01	Subtotal Direct and Indirect Capital Costs			$ 3,680,220
3.02	Contingency	25%		$ 920,055
Total Capital Costs				$ 4,600,275
Item	**Description**	**Quantity**	**Unit**	**Cost**
Annual Direct O&M Costs				
1.01	Semi-Annual Groundwater Monitoring Event	2	$ 20,000	$ 40,000
1.02	Semi-Annual Site Inspection	2	$ 10,000	$ 20,000
1.03	Semi-Annual Summary Report	2	$ 5,000	$ 5,000
1.04	Annual Maintenance	1	$ 5,000	$ 5,000
Total Annual Direct O&M Costs				$ 70,000
Annual Indirect O&M Costs				
2.01	Administrative Costs	10%		$ 7,000
Total Annual Indirect O&M Costs				$ 7,000
Subtotal Annual O&M Costs				
3.01	Subtotal Direct and Indirect Annual O&M Costs			$ 77,000
3.02	Contingency	25%		$ 19,250
Total Annual O&M Costs				$ 96,250

30 Year Cost Projection			
Total Capital Costs			$ 4,600,275
Present Worth of 30 Years Annual O&M	5%		$ 1,479,598
Total Cost: Alternative 5 - North Area ISCO (ISBS)			$ 6,079,873

TABLE E-1B

COST ESTIMATE - REMEDIAL ALTERNATIVE 5B
NOTH AREA IN-SITU CHEMICAL OXIDATION (ISBS) - ALL ZONES
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Item	Description	Quantity	Unit	Cost
Direct Capital Costs				
1.01	Monitoring Well Replacement	3	$ 3,000	$ 9,000
1.02	Pilot Scale Study	1	$ 450,000	$ 450,000
1.03	Shallow Zone ISCO Drilling (LF)	4480	$ 25	$ 112,000
	Intermediate Aquitard ISCO Drilling (LF)	29790	$ 35	$ 1,042,650
	Intermediate Zone ISCO Drilling (LF)	1850	$ 35	$ 64,750
	Shallow Zone & Interm. Aquitard ISCO Drilling (LF)	18750	$ 35	$ 656,250
	Shallow Zone & Interm. Zone Drilling (LF)	3870	$ 35	$ 135,450
	Interm. Aquitard and Interm. Zone Drilling (LF)	11480	$ 35	$ 401,800
	Shallow & Interm. Zones & Interm. Aquitard Drilling (LF)	40200	$ 35	$ 1,407,000
	Total Drilling @ 140 feet per day production	4480		
	Total Drilling @ 100 feet per day production	105940		
1.04	Shallow Zone Oxidant (CY)	56360	$ 50	$ 2,818,000
	Intermediate Aquitard Oxidant (CY)	57930	$ 50	$ 2,896,500
	Intermediate Zone Oxidant (CY)	12941	$ 50	$ 647,050
Total Direct Capital Costs				$ 10,640,450
Indirect Capital Costs				
2.01	Engineering and Design	2%		$ 212,809
2.02	Permitting and Fees	1%		$ 106,405
2.03	Construction Oversight (includes H&S)	1092	$ 1,200	$ 1,310,400
Total Indirect Capital Costs				$ 1,629,614
Subtotal Capital Costs				
3.01	Subtotal Direct and Indirect Capital Costs			$ 12,270,064
3.02	Contingency	25%		$ 3,067,516
Total Capital Costs				$ 15,337,579
Item	**Description**	**Quantity**	**Unit**	**Cost**
Annual Direct O&M Costs				
1.01	Semi-Annual Groundwater Monitoring Event	2	$ 20,000	$ 40,000
1.02	Semi-Annual Site Inspection	2	$ 10,000	$ 20,000
1.03	Semi-Annual Summary Report	2	$ 5,000	$ 5,000
1.04	Annual Maintenance	1	$ 5,000	$ 5,000
Total Annual Direct O&M Costs				$ 70,000
Annual Indirect O&M Costs				
2.01	Administrative Costs	10%		$ 7,000
Total Annual Indirect O&M Costs				$ 7,000
Subtotal Annual O&M Costs				
3.01	Subtotal Direct and IndirectAnnual O&M Costs			$ 77,000
3.02	Contingency	25%		$ 19,250
Total Annual O&M Costs				$ 96,250

30 Year Cost Projection			
Total Capital Costs			$ 15,337,579.38
Present Worth of 30 Years Annual O&M	5%		$1,479,598.41
Total Cost: Alternative 5 - North Area ISCO (ISBS)			$ 16,817,177.79

TABLE E-1C

SUPPORT COST ESTIMATE CALCULATIONS - REMEDIAL ALTERNATIVE 5
NOTH AREA IN-SITU CHEMICAL OXIDATION (ISBS)
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Determine Number of Injection Points and Linear Feet of Drilling - Shallow Zone Only

Injection Zone of Interest	Area (sf)	Area/Point (sf/point)	Number of Points	Depth (ft)	Total Length (ft)	Note
Shallow Zone Only (0-20 ft, 15 ft oc)	117194	225	520	20	10400	A
Totals	***117194***		***520***			

A - The area of the shallow zone impacts is 15569 + 34989 + 6512 + 20772 + 10259 + 14125 +14698 square feet as shown on Figure E-2.

Determine Number of Injection Points and Linear Feet of Drilling - Shallow Zone, Intermediate Aquitard, and Intermediate Zones

Injection Zone of Interest	Area (sf)	Area/Point (sf/point)	Number of Points	Depth (ft)	Total Length (ft)	Note
Shallow Zone Only (0-20 ft, 15 ft oc)	50558	225	224	20	4480	A
Interm. Aquitard Only (20-50 ft, 10 ft oc)	99370	100	993	30	29790	B
Intermediate Zone Only (50-60 ft, 15 ft oc)	41754	225	185	10	1850	C
Shallow Zone & Interm. Aquitard (0-50 ft, 10 ft oc)	37543	100	375	50	18750	D
Shallow Zone & Interm. Zone (0-20 & 50-60 ft, 15 ft oc)	29093	225	129	30	3870	E
Interm. Aquitard & Interm. (20-60 ft, 10 ft oc)	28730	100	287	40	11480	F
Shallow zone, Interm. Aquitard & Interm. (0-60 ft, 10 ft oc)	67040	100	670	60	40200	G
Totals	***354088***		***2,863***			

A - The area of the shallow zone impacts is 15569 + 34989 square feet as shown on Figure E-2.

B - The area of the intermediate aquitard impacts is 99370 square feet as shown on Figure E-2.

C - The area of the intermediate zone impacts is 41754 square feet as shown on Figure E-2..

D - The area of the shallow zone and intermediate aquitard impacts is 6512 + 20772 + 10259 square feet as shown on Figure E-2.

E - The area of the shallow zone and intermediate zone impacts is 14125 + 14968 square feet as shown on Figure E-2.

F - The area of the intermediate aquitard and intermediate zone impacts is 28730 square feet as shown on Figure E-2..

G - The area of the shallow zone, intermediate aquitard, and intermediate zone impacts is 67040 square feet as shown on Figure E-2.

TABLE E-2A

COST ESTIMATE - REMEDIAL ALTERNATIVE 6
NORTH AREA IN-SITU STABILIZATION/SOLIDIFICATION - SHALLOW ZONE ONLY
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Item	Description	Quantity	Unit	Cost
Direct Capital Costs				
1.01	Monitoring Well Replacement	3	$ 3,000	$ 9,000
1.02	Bench Scale Testing	1	$ 18,000	$ 18,000
1.03	In-Situ Stabilization/Solidification - Shallow Zone	56360	$ 75	$ 4,227,000
Total Direct Capital Costs				$ 4,254,000
Indirect Capital Costs				
2.01	Engineering and Design	5%		$ 212,700
2.02	Permitting and Fees	1%		$ 42,540
2.03	Construction Oversight (includes H&S)	75	$ 1,200	$ 90,000
Total Indirect Capital Costs				$ 345,240
Subtotal Capital Costs				
3.01	Subtotal Direct and Indirect Capital Costs			$ 4,599,240
3.02	Contingency	25%		$ 1,149,810
Total Capital Costs				$ 5,749,050
Item	**Description**	**Quantity**	**Unit**	**Cost**
Annual Direct O&M Costs				
1.01	Semi-Annual Groundwater Monitoring Event	2	$ 20,000	$ 40,000
1.02	Semi-Annual Site Inspection	2	$ 10,000	$ 20,000
1.03	Semi-Annual Summary Report	2	$ 5,000	$ 5,000
1.04	Annual Maintenance	1	$ 5,000	$ 5,000
Total Annual Direct O&M Costs				$ 70,000
Annual Indirect O&M Costs				
2.01	Administrative Costs	10%		$ 7,000
Total Annual Indirect O&M Costs				$ 7,000
Subtotal Annual O&M Costs				
3.01	Subtotal Direct and IndirectAnnual O&M Costs			$ 77,000
3.02	Contingency	25%		$ 19,250
Total Annual O&M Costs				$ 96,250

30 Year Cost Projection			
Total Capital Costs			$ 5,749,050
Present Worth of 30 Years Annual O&M	5%		$ 1,479,598
Total Cost: Alternative 6 - North Area ISSS			$ 7,228,648

TABLE E-2B

COST ESTIMATE - REMEDIAL ALTERNATIVE 6A
NORTH AREA IN-SITU STABILIZATION/SOLIDIFICATION - ALL ZONES
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Item	Description	Quantity	Unit	Cost
Direct Capital Costs				
1.01	Monitoring Well Replacement	3	$ 3,000	$ 9,000
1.02	Bench Scale Testing	1	$ 18,000	$ 18,000
1.02	In-Situ Stabilization/Solidification - Shallow Zone	56360	$ 75	$ 4,227,000
1.03	In-Situ Stabilization/Solidification - Interm. Aquitard	57930	$ 75	$ 4,344,750
1.04	In-Situ Stabilization/Solidification - Interm. Zone	12941	$ 75	$ 970,575
Total Direct Capital Costs				$ 9,569,325
Indirect Capital Costs				
2.01	Engineering and Design	2.5%		$ 239,233
2.02	Permitting and Fees	1%		$ 95,693
2.03	Construction Oversight (includes H&S)	1092	$ 1,200	$ 1,310,400
Total Indirect Capital Costs				$ 1,645,326
Subtotal Capital Costs				
3.01	Subtotal Direct and Indirect Capital Costs			$ 11,214,651
3.02	Contingency	25%		$ 2,803,663
Total Capital Costs				$ 14,018,314
Item	**Description**	**Quantity**	**Unit**	**Cost**
Annual Direct O&M Costs				
1.01	Semi-Annual Groundwater Monitoring Event	2	$ 20,000	$ 40,000
1.02	Semi-Annual Site Inspection	2	$ 10,000	$ 20,000
1.03	Semi-Annual Summary Report	2	$ 5,000	$ 5,000
1.04	Annual Maintenance	1	$ 5,000	$ 5,000
Total Annual Direct O&M Costs				$ 70,000
Annual Indirect O&M Costs				
2.01	Administrative Costs	10%		$ 7,000
Total Annual Indirect O&M Costs				$ 7,000
Subtotal Annual O&M Costs				
3.01	Subtotal Direct and IndirectAnnual O&M Costs			$ 77,000
3.02	Contingency	25%		$ 19,250
Total Annual O&M Costs				$ 96,250

30 Year Cost Projection			
Total Capital Costs			$ 14,018,314
Present Worth of 30 Years Annual O&M	5%		$ 1,479,598
Total Cost: Alternative 6 - North Area ISSS			$ 15,497,913

FIGURE E-1A - SHALLOW ZONE DNAPL EXTENT

FIGURE E-1B - INTERMEDIATE AQUITARD DNAPL EXTENT

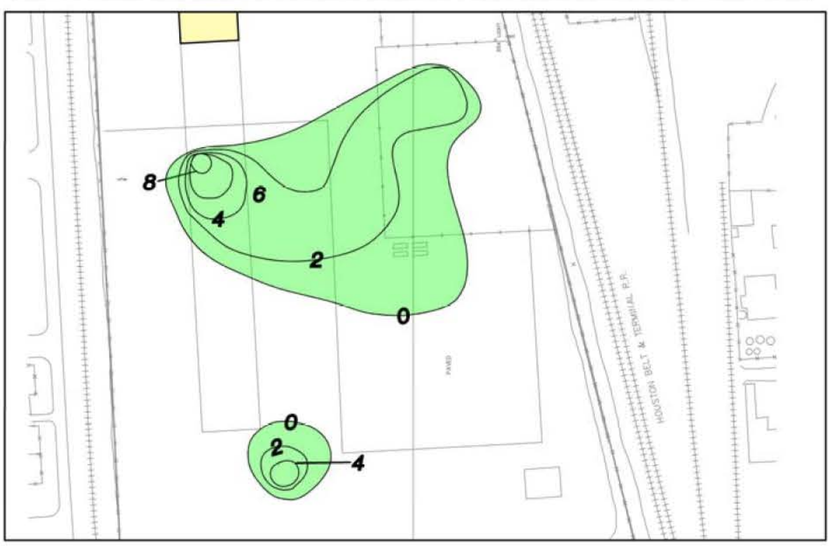


FIGURE E-1C - INTERMEDIATE ZONE DNAPL EXTENT

LEGEND:

- SHALLOW ZONE DNAPL EXTENT (AREA = ~182,000 SF)
- INTERMEDIATE AQUITARD DNAPL EXTENT (AREA = ~232,000 SF)
- INTERMEDIATE ZONE DNAPL EXTENT (AREA = ~166,000 SF)
- OFFICE BUILDING, SHOP, WAREHOUSE, OR MAINTENANCE BAY
- LATERAL EXTENT OF DNAPL

SOIL VOLUMES BASED ON DNAPL ISOPACHS (CY)				
AFFECTED THICKNESS			AFFECTED AREA (FT2)	AFFECTED VOLUME (CY)
PERIMETER (FT)	INTERIOR (FT)	AVERAGE (FT)		
NORTH AREA SHALLOW ZONE (NORTHERN MASS)				
0	10	5	50832	9413
10	15	12.5	65449	30300
15	17	16	5555	3292
NORTH AREA SHALLOW ZONE (SOUTHERN MASS)				
0	5	2.5	28597	2648
5	10	7.5	16239	4511
10	12	11	15208	6196
NORTH AREA INTERMEDIATE AQUITARD				
0	5	2.5	94531	8753
5	10	7.5	106934	29704
10	20	15	24891	13828
20	30	25	4424	4096
30	33	31.5	1327	1548
NORTH AREA INTERMEDIATE ZONE (NORTHERN MASS)				
0	2	1	81008	3000
2	4	3	60715	6746
4	6	5	5376	996
6	8	7	3646	945
8	8	8	903	268
NORTH AREA INTERMEDIATE ZONE (SOUTHERN MASS)				
0	2	1	10085	374
2	4	3	2977	331
4	5	4.5	1693	282
Total Volume - Shallow Zone (CY)				56360
Total Volume - Intermediate Aquitard (CY)				57930
Total Volume - Intermediate Zone (CY)				12941

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRWN: TDD	DATE: 03/02/12
CHKD: RJH	DATE: 03/02/12
APPD: JSZ	DATE: 03/02/12
SCALE:	AS SHOWN

KEY ENVIRONMENTAL INCORPORATED

FOCUSED FEASIBILITY STUDY ADDENDUM
ISSS TECHNOLOGY ALTERNATIVE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

REFERENCE:

ISSUE DATE:

KEY ENVIRONMENTAL, INC.
200 THIRD AVENUE
CARNEGIE, PA 15106

INFERRED EXTENT OF DNAPL

PROJECT NO: 11-318

FIGURE E-1

FIGURE E-2A - SHALLOW ZONE DNAPL EXTENT

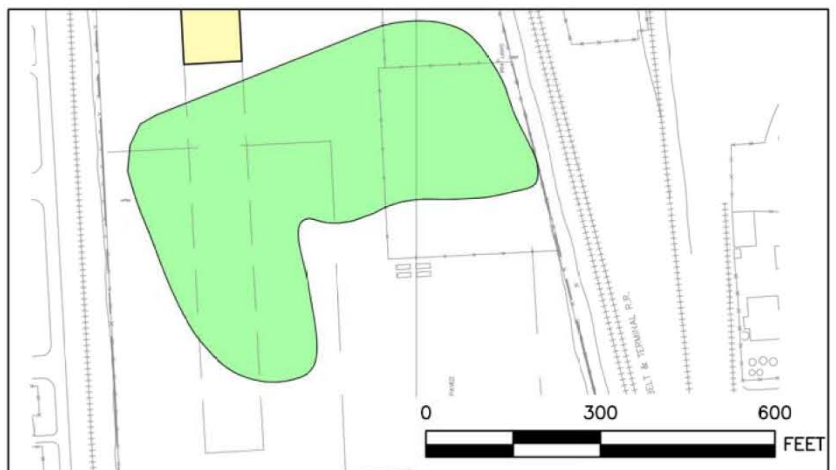


FIGURE E-2B - INTERMEDIATE AQUITARD DNAPL EXTENT

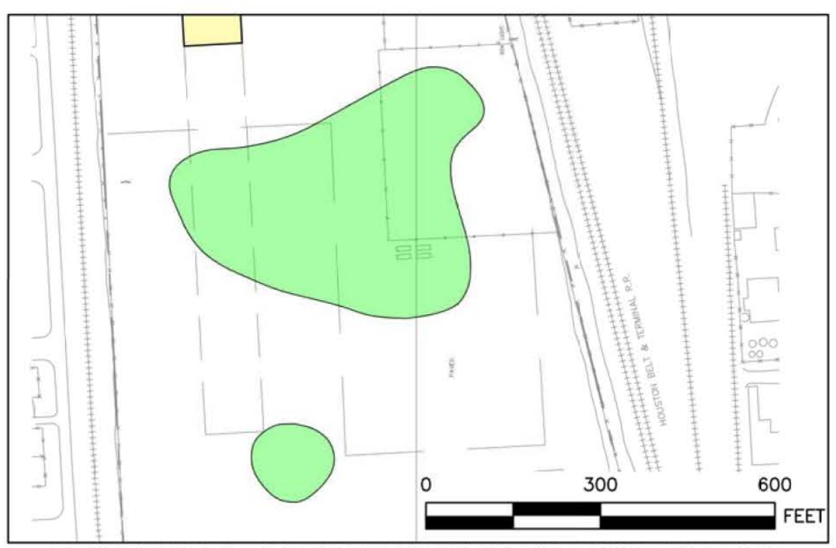


FIGURE E-2C - INTERMEDIATE ZONE DNAPL EXTENT

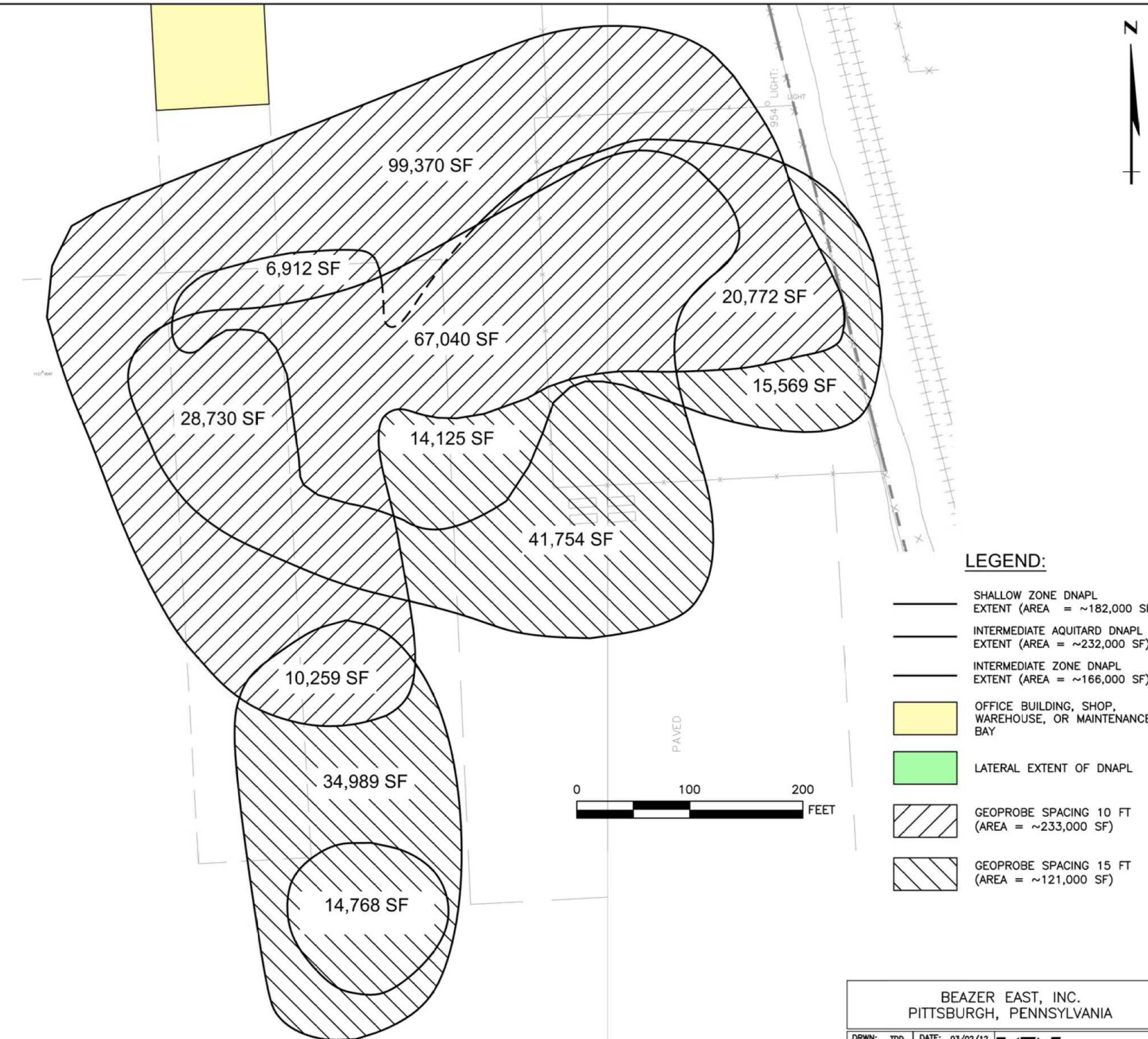


FIGURE E-2D - COMPOSITE DNAPL EXTENT AND ISCO TREATMENT AREAS / DEPTH INTERVALS

LEGEND:

- SHALLOW ZONE DNAPL EXTENT (AREA = ~182,000 SF)
- INTERMEDIATE AQUITARD DNAPL EXTENT (AREA = ~232,000 SF)
- INTERMEDIATE ZONE DNAPL EXTENT (AREA = ~166,000 SF)
- OFFICE BUILDING, SHOP, WAREHOUSE, OR MAINTENANCE BAY
- LATERAL EXTENT OF DNAPL
- GEOPROBE SPACING 10 FT (AREA = ~233,000 SF)
- GEOPROBE SPACING 15 FT (AREA = ~121,000 SF)

REV #	DATE	DESCRIPTION	APPD

REFERENCE:

ISSUE DATE:

KEY ENVIRONMENTAL, INC.
200 THIRD AVENUE
CARNEGIE, PA 15106

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRWN: TDD	DATE: 03/02/12	
CHKD: RJH	DATE: 03/02/12	
APPD: JSZ	DATE: 03/02/12	
SCALE: AS SHOWN		

KEY ENVIRONMENTAL INCORPORATED

FOCUSED FEASIBILITY STUDY ADDENDUM
ISCO TECHNOLOGY ALTERNATIVE
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

ISCO TREATMENT AREAS

PROJECT NO: 11-318
FIGURE E-2